Chapter 6.
Industry, Technology, and the Global Marketplace

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Highlights

Knowledge and Technology Infrastructure in the World Economy

Knowledge- and technology-intensive (KTI) industries have been a major and growing part of the global economy.

- Ten KTI industries, consisting of five knowledge-intensive (KI) services industries and five high-technology (HT) manufacturing industries, represented 29% of world gross domestic product (GDP) in 2014.
- The commercial KI services—business, financial, and information—have the highest share of GDP (17%). The public KI services—education and health—have a 9% share.
- The HT manufacturing industries—aircraft and spacecraft; communications and semiconductors; computers; pharmaceuticals; and testing, measuring, and control instruments—have a combined 2% share of world GDP.

The United States has the highest KTI share of GDP of any large economy.

- KTI industries accounted for 39% of the U.S. economy in 2014. The KTI concentrations for the European Union (EU) and Japan were considerably lower at 30% each.
- Major developing countries have lower KTI shares than developed countries. The KTI shares in Brazil, China, and India were 19%–21%.

Worldwide Distribution of Knowledge- and Technology-Intensive Industries

The United States had the largest global shares of commercial KI services in 2014.

- The United States accounted for 33% of global commercial KI services (business, financial, and information), followed by the EU (25%).
- China's commercial KI services industries continued to grow rapidly, and China surpassed Japan to become the world's third-largest provider with a global share of 10%.
- In HT manufacturing, the United States and China are the largest global producers (29% and 27% global share, respectively). China surpassed both Japan and the EU in the late 2000s.

U.S. KTI industries have had a stronger recovery from the global recession than those in the EU and Japan.

- Value-added output of U.S. commercial KI services in 2014 was 23% higher than in 2008. Output in the EU and Japan was stagnant.
- Output of U.S. HT manufacturing industries was 18% higher in 2014 than in 2008. The EU's and Japan's output contracted.

KTI industries play a special role in the U.S. economy and in U.S. business R&D.

- U.S. commercial KI services industries employ one in seven U.S. workers (20 million), pay higher-than-average wages, have an above-average share of skilled workers, and fund 29% of U.S. business R&D.

- U.S. HT manufacturing industries, although much smaller than commercial KI services industries, employ 1.8 million workers, have a higher share of highly skilled workers, and fund nearly half of U.S. business R&D.
- Value-added output had a strong recovery, but not employment. The number of jobs in commercial KI services in 2014 was slightly above the pre-recession levels but remains lower than pre-recession levels in HT manufacturing.

Trade and Other Globalization Indicators

The EU is the world's leading exporter of commercial KI services, followed by the United States; both have substantial surpluses in this trade.

- The EU's commercial KI services exports more than doubled to reach nearly $500 billion between 2004 and 2013.
- U.S. exports of commercial KI services grew as fast as the EU's over this period, reaching $271 billion.
- China and India's KTI exports grew rapidly, resulting in their global export shares each reaching 7% in 2013.

Global trade in HT manufactured goods: lesser role for developed countries.

- China is the world's largest exporter of HT products, with a 24% global share and a surplus of $130 billion. But China's value-added exports and trade surplus are likely lower because China imports components and inputs from the United States, the EU, and Asia for final assembly in China.
- U.S. HT exports grew from $157 billion in 2003 to $302 billion in 2014. The U.S. global share of HT exports declined slightly to 12% in 2014; the U.S. HT trade deficit narrowed to $41 billion.
- The U.S. trade deficit in HT goods is largely anchored in products in information and communications technologies—communications, computers, and semiconductors. In other HT manufactured goods, notably aircraft and spacecraft, the United States has a substantial trade surplus.

Innovation-Related Indicators of the United States and Other Major Economies

U.S. firms in commercial KTI industries reported much higher incidences of innovation—the introduction into the marketplace of a new product or service—than firms in other industries.

- Five HT manufacturing industries—aircraft; computers; communications and semiconductors; testing, measuring, and control instruments; and pharmaceuticals—reported rates of product innovation that were at least double the U.S. manufacturing sector average.
- In the U.S. nonmanufacturing sector, software firms had the highest rate of innovation, with 69% of companies reporting the introduction of a new product or service compared with the 9% average for all nonmanufacturing companies.
- The rate of innovation in computer systems design; data processing, hosting, and related services; and scientific R&D services is two to three times higher than the nonmanufacturing average.

Inventors in the United States received nearly half of U.S. Patent and Trademark Office (USPTO) patents granted in 2013. Japan and the EU were the second- and third-largest recipients.

- The share of patents granted by USPTO to U.S. inventors declined from 52% in 2003 to 48% in 2014. Strong growth in China, India, South Korea, and Taiwan pushed up their global shares during this period.
- U.S. inventors are relatively more active in patenting several advanced and science-based technologies, including information technology management, digital communications, medical technology, pharmaceuticals, and biotechnology.

Japan is the leading recipient of triadic patents, closely followed by the EU and the United States. Triadic patents are considered an indicator of higher-value inventions.

- Triadic patents are patents sought for protection in the world's largest markets—the United States, Europe, and Japan.
- The share of triadic patents granted to the United States and Japan each fell slightly over the last decade. China's share quadrupled to reach 4%, consistent with its rapid growth in USPTO patents.

Investment and Innovation in Clean Energy Technologies

Global commercial energy investment in 2014 was $281 billion, largely concentrated in solar and wind technologies. China leads the United States and the EU in attracting clean energy investment.

- Clean energy investment in China, largely in solar and wind technologies, rose steeply over the last decade to reach $86 billion in 2014. China led the world in attracting commercial clean energy investment (31% global share).
- The United States was the third largest (behind the EU) in attracting clean energy investment. U.S. investment has been about $40 billion in 2012–14, down from its peak of $57 billion in 2011 because of policy uncertainty and the falling per-unit cost of investment in solar and wind technology.
- Commercial investment in the EU fell sharply because of cutbacks in clean energy incentives in many countries in response to the EU's recession, scheduled tapering of temporary support, and falling per-unit cost of investing in solar and wind technologies. The EU's global share fell from 40% in 2011 to 18% in 2014.

The EU, the United States, and Japan were the largest investors in 2013 in public research, development, and demonstration (RD&D) of clean energy and other non-fossil fuel technologies.

- Global expenditures on public RD&D of clean energy and other non-fossil fuel technologies was an estimated $12.7 billion in 2013. Renewables was the largest area, receiving $3.7 billion. The next two largest areas were nuclear ($3.4 billion) and energy efficiency ($3.2 billion).
- The EU was the largest investor in public RD&D of these technologies ($4.4 billion), followed by the United States ($3.5 billion) and Japan ($2.6 billion).
- U.S. public RD&D investment increased from $2.2 billion to $3.5 billion (2006 to 2013), driven by increases in solar, biofuels, and energy efficiency.

Introduction

Chapter Overview

Policymakers in many countries increasingly emphasize the central role of knowledge, particularly R&D and other activities that advance science and technology (S&T), in a country's economic growth and competitiveness. This chapter examines the downstream effects of these activities—their embodiment in goods and services—on the performance of the United States and other major economies in the global marketplace.

This chapter covers two main areas. The first is knowledge- and technology-intensive (KTI) industries; the second focuses on innovation.

KTI industries encompass both service and manufacturing sectors, based on 10 categories of industries classified by the Organisation for Economic Co-operation and Development (OECD 2001, 2007) that have a particularly strong link to S&T:[i]

- Five knowledge-intensive (KI) services industries incorporate high technology (HT) either in their services or in the delivery of their services. Three of these—financial, business, and information services (including computer software and R&D)—are generally commercially traded. The others—education and health services—are publicly regulated or provided and remain relatively more location bound.
- Five HT manufacturing industries spend a large proportion of their revenues on R&D and make products that contain or embody technologies developed from R&D. These are aircraft and spacecraft, pharmaceuticals, computers and office machinery, semiconductors and communications equipment (treated separately in the text), and scientific (medical, precision, and optical) instruments.[ii] Aircraft and spacecraft and pharmaceuticals are less market driven than the other three industries because of public funding, procurement, and regulation.[iii]

This chapter gives special attention to KTI industries in information and communications technology (ICT). ICT combines the HT manufacturing industries of computers and office machinery, communications equipment, and semiconductors with the KI services of information and computer programming (a subset of business services). ICT industries are important because they provide the infrastructure for many social and economic activities, and they facilitate innovation and economic growth.[iv] Non-KTI industries are also very important in the world economy and therefore receive some attention in this chapter (see sidebar, Industries That Are Not Knowledge or Technology Intensive).

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[i] See OECD (2001) for a discussion of classifying economic activities according to their degree of "knowledge intensity." Like all classification schemes, the OECD classification has shortcomings. For example, KTI industries produce some goods or services that are neither knowledge intensive nor technologically advanced. In addition, multiproduct companies that produce a mix of goods and services, only some of which are KTI, are assigned to their largest business segment. Nevertheless, data based on the OECD classification allows researchers and analysts to trace, in broad outline, worldwide trends toward greater interdependence in science and technology and the development of KTI sectors in many of the world's economies.

[ii] In designating these HT manufacturing industries, the OECD estimated the degree to which different industries used R&D expenditures made directly by firms in these industries and R&D embedded in purchased inputs (indirect

R&D) for 13 countries: the United States, Japan, Germany, France, the United Kingdom, Canada, Italy, Spain, Sweden, Denmark, Finland, Norway, and Ireland. Direct R&D intensities were calculated as the ratio of total R&D expenditure to output (production) in 22 industrial sectors. Each sector was weighted according to its share of the total output among the 13 countries, using purchasing power parities as exchange rates. Indirect intensities were calculated using the technical coefficients of industries on the basis of input-output matrices. The OECD then assumed that, for a given type of input and for all groups of products, the proportions of R&D expenditure embodied in value added remained constant. The input-output coefficients were then multiplied by the direct R&D intensities. For further details concerning the methodology used, see OECD (2001). It should be noted that several nonmanufacturing industries have R&D intensities equal to or greater than those of industries designated by the OECD as HT manufacturing. For additional perspectives on the OECD's methodology, see Godin (2004).

[iii] Aircraft and spacecraft trends are affected by public funding for military aircraft, missiles, and spacecraft, and by different national flight regulations. Public funding and regulation of drug approval, prices, patent protection, and importation of foreign pharmaceuticals can affect pharmaceuticals.

[iv] See Atkinson and McKay (2007:16–17) for a discussion of and references to the impact of IT on economic growth and productivity.

Industries That Are Not Knowledge or Technology Intensive

Science and technology (S&T) are used in many industries besides HT manufacturing and KI services. Service industries not classified as KI services—which include wholesale and retail trade, restaurant and hotel, transportation and storage, and real estate—may incorporate advanced technology in their services or in the delivery of their services. Manufacturing industries not classified as HT by the Organisation for Economic Co-operation and Development (OECD) may use advanced manufacturing techniques, incorporate technologically advanced inputs in manufacturing or perform or rely on R&D. Industries not classified as either manufacturing or services—agriculture, construction, mining, and utility—also may incorporate recent S&T in their products and processes. For example, agriculture relies on breakthroughs in biotechnology, construction uses knowledge from materials science, mining depends on earth sciences, and utilities rely on advances in energy science.

In the non-KI services industries—wholesale and retail trade, restaurant and hotel, transportation and storage, and real estate—patterns and trends of the four largest producers, the United States, the EU, Japan, and China, were similar to those in HT manufacturing and commercial KI services (Table 6-A). The United States and the EU, the two largest providers, had modest declines in their global shares of value added between 1999 and 2014. Japan's share declined more sharply. China's global share grew rapidly to surpass or reach Japan's share in restaurant and hotel, transportation and storage, and wholesale and retail during this period.

Table 6-A **Global value added for selected industries, by selected region/country/economy: 2014**

(Percent)

Region/country/economy	Agriculture	Construction	Mining	Real estate	Restaurants and hotels	Transport and storage	Wholesale and retail
Global value added (current $billions)	3,042	3,987	3,538	6,219	1,817	3,093	8,515
China	31.0	17.7	16.3	8.8	11.3	15.6	12.3
EU	9.7	22.6	3.5	26.9	25.6	23.8	20.9
Japan	2.4	8.5	0.1	10.0	9.1	8.0	7.7
United States	7.7	17.3	14.3	35.2	26.3	16.5	25.4

NOTES: EU = European Union.

Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.

SOURCE: IHS Global Insight, World Industry Service database (2014).

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Non-HT manufacturing industries are divided into three categories, as classified by the OECD: medium-high technology, medium-low technology, and low technology.* In these industries, patterns and trends were somewhat divergent from those in HT manufacturing (Table 6-B). China's global share of value added grew rapidly between 1999 and 2014, and it became the world's largest manufacturer in the three non-HT manufacturing segments. The global shares of the United States and the EU declined sharply in contrast to their relatively more stable positions in HT manufacturing. Japan's share also declined sharply in all three segments.

Table 6-B **Global value added for manufacturing industries, by selected technology level and selected region/country/economy: 2014**

(Percent)

Region/country/economy	Medium high	Medium low	Low
Global value added (current $billions)	3,840	3,756	3,734
China	31.5	35.4	34.3
EU	21.2	16.2	19.3
Japan	8.8	7.4	6.0
United States	17.1	14.0	15.2

NOTES: EU = European Union.

Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. The technology level of manufacturing is

	classified by the Organisation for Economic Co-operation and Development on the basis of R&D intensity of output. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia.
SOURCE:	IHS Global Insight, World Industry Service database (2014).
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The positions of the United States, the EU, China, and Japan in nonmanufacturing and nonservices industries—agriculture, construction, and mining—are fairly similar to their positions in KTI industries (Table 6-A). China's global share grew rapidly between 1999 and 2014, and it became the world's largest producer in agriculture and mining. The global shares of the United States and the EU fell moderately. Japan had a steeper decline in these industries.

* Medium-high technology includes motor vehicle manufacturing and chemicals production, excluding pharmaceuticals; medium-low technology includes rubber and plastic production and basic metals; and low technology includes paper and food product production.

The globalization of the world economy involves the rise of new centers of KTI industries.[v] Although the United States continues to be a leader in these industries, China, India, Brazil, and other developing economies have vigorously pursued national innovation policies in an effort to become major producers and exporters of KTI goods and services. Advances in S&T have enabled companies to spread KTI activity to more locations around the globe and to develop strong interconnections among geographically distant entities.

Innovation, the second major focus of the chapter, is closely associated with technologically led economic growth. Therefore, the analysis of innovation focuses on the role of KTI industries. The measurement of innovation is an emerging field, and current data and indicators are limited. However, activities related to commercializing inventions and new technologies are important components of innovation indicators. Such activities include patenting, financing new HT firms, and investing in intangible goods and services.

This chapter pays special attention to clean energy technologies. In recent years, innovations aimed at developing improved technologies for generating clean and affordable energy have become increasingly important in developed and developing countries. Energy has a strong link to S&T and, like ICT, is a key element of infrastructure. Its availability affects prospects for growth and development, with clean energy an increasingly important element of energy infrastructure.

Several themes cross-cut the various indicators examined in the chapter:

- The HT manufacturing industries are the most globalized among the KTI industries. Two HT manufacturing industries—communications; and semiconductors and computers—have the most complex global value chains, where China is the dominant locale for final production.
- KTI industries remain concentrated in developed countries despite much more rapid growth by China and other developing countries. Developed countries account for three-fourths of global production of commercial KI services industries, which are the largest category of KTI industries.
- Globalization is increasing rapidly in the much larger commercial KI services industries but remains substantially lower than in HT manufacturing. Data on trade and U.S. foreign investment suggest that these industries have substantial linkages among developed countries. Industries in developed countries also contract out some of their activities to developing countries.
- Although KTI activity has increased in Brazil, India, Indonesia, Turkey, and other developing countries, China plays a unique role in this arena. Despite a per capita income comparable with that of other developing

countries, China's economic activity in several KTI industries has grown unusually quickly and is now comparable with or exceeds that of the United States, the European Union (EU; see "Glossary" for member countries), and Japan.

- KTI industries in developing countries have recovered more strongly and have been growing faster after the 2008–09 global recession than in developed countries. Among the KTI industries in developed countries, those in the United States rebounded most robustly from the economic downturn.

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[v] See Mudambi (2008) and Reynolds (2010) for a discussion of the shift to knowledge-based production and geographical dispersion of economic activity.

Chapter Organization

This chapter focuses on the United States, the EU, Japan, and the large and rapidly developing economy of China. Other major developing countries, including Brazil, India, and Indonesia, also receive attention. The time span is from the late 1990s to the present.

This chapter is organized into five sections:

- The first section discusses the prominent role of KTI industries in regional and national economies around the world.
- The second section describes the global spread of KTI industries and analyzes regional and national shares of worldwide production. It discusses shares for the KTI industry group as a whole, for KI services and HT manufacturing overall, and for particular services and manufacturing industries within these groups. Because advanced technology is increasingly essential for non-HT industries, some data on these industries are also presented.
- The third section examines indicators of increased interconnection of KTI industries in the global economy. Data on patterns and trends in global trade in KTI industries make up the bulk of this section. Data on domestic and foreign production and on employment in U.S. multinational companies (MNCs) in KTI industries are presented as indicators of the increasing involvement of these economically important firms in cross-border activities. To further illustrate the effects of globalization on the United States, the section presents data on U.S. and foreign direct investment abroad, showing trends by region and for individual KTI industries.
- The fourth section presents innovation-related indicators. It examines countries' shares in all patents granted by the United States in various technology areas. It next examines countries' shares of high-value patents. It presents innovation-related data on U.S. industries. In addition, it presents data on global venture capital investment, an important financing source for small HT-based firms.
- The last section presents data on clean energy and related technologies, which have become a policy focus in many developed and developing nations. These energy technologies, like KTI industries, are closely linked to scientific R&D. Production, investment, and innovation in these energies and technologies are rapidly growing in the United States and other major economies.

Data Sources, Definitions, and Methodology

This chapter uses a variety of data sources. Although several are thematically related, they have different classification systems. The sidebar Data Sources describes these systems and aims to clarify the differences among them. The discussion of regional and country patterns and trends includes an examination of developed and developing countries using the International Monetary Fund's categorization. Countries classified by the Fund as *advanced* are developed countries, whereas those classified as *emerging* and *developing* are considered to be developing.

Data Sources

This chapter uses a variety of data sources. Although several are thematically related, they have different classification systems. The below Table 6-C, describes these systems and aims to clarify the differences among them.

Table 6-C Data Sources

Topic	Data Provider	Variables	Basis of classification	Coverage	Methodology
Knowledge-intensive (KI) services and high-technology (HT) manufacturing industries	IHS Global Insight, World Industry Service database (proprietary)	Production, value added	Industry basis using International Standard Industrial Classification of All Economic Activities	KI services — business, financial, information, health, and education HT manufacturing — aircraft and spacecraft, pharmaceuticals, office and computer equipment, communications, and scientific and measuring equipment	Uses data from national statistical offices in developed countries and some developing countries and estimates by IHS Global Insight for some developing countries
		ICT expenditures, by businesses	ICT consumer spending of population, by country ICT business spending, by	Not applicable	Uses data from national statistical offices and other sources and estimates by IHS Global

Topic	Data Provider	Variables	Basis of classification	Coverage	Methodology
Information and communications technologies (ICT) spending	IHS Global Insight, Global ICT Navigator (proprietary database)	and consumers	category of industry and by country		Insight for some developing countries
Trade in commercial KI services	World Trade Organization	Exports and imports	Product basis using Extended Balance of Payments Services classification	KI services — business, financial, information, and royalties and fees	Uses data from national statistical offices, the International Monetary Fund, and other sources
Trade in HT goods	IHS Global Insight, World Trade Service database (proprietary)	Exports and imports	Product basis using Standard International Trade Classification	Aerospace, pharmaceuticals, office and computing equipment, communications equipment, and scientific and measuring instruments	Uses data from national statistical offices and estimates by IHS Global Insight
Globalization of U.S. multinationals	U.S. Bureau of Economic Analysis (BEA)	Value added, employment, and inward and outward direct investment	Industry basis using North American Industrial Classification System (NAICS) Investment position on a historical cost, which is based on the value recorded in the financial accounts of the enterprise at	Commercial KI services — business, financial, and information HT manufacturing — aerospace, pharmaceuticals, office and computer equipment, communications, and scientific and	BEA annual surveys of U.S. multinationals and U.S. subsidiaries of non-U.S. multinationals

Topic	Data Provider	Variables	Basis of classification	Coverage	Methodology
			the time the asset was acquired	measuring equipment	
U.S. industry innovation activities	National Science Foundation, Business R&D and Innovation Survey	Innovation activities	U.S. businesses with more than five employees	Industries classified on an industry basis using NAICS	Survey of U.S.-based businesses with more than five employees using a nationally representative sample
U.S. Patent and Trademark Office (USPTO) patents	Science-Metrix/SRI International/Scopus /LexisNexis	Patent grants	Inventor country of origin, technology area as classified by the Patent Board	More than 400 U.S. patent classes, inventors classified according to country of origin and technology codes assigned to the grant	Source of data is USPTO
Triadic patent families	Organisation for Economic Co-operation and Development (OECD)	Patent applications	Inventor country of origin and selected technology area as classified by the OECD	Broad technology areas as defined by the OECD, inventors classified according to country of origin	Sources of data are USPTO, European Patent Office, and Japan Patent Office
Venture capital	Dow Jones VentureSource	Investment, technology area, country of investor origin	Technology areas as classified by the Dow Jones classification system	Twenty-seven technology areas, investment classified by venture firms' country location	Data collected by analysts from public and private sources, such as public announcements of venture capital investment deals

Topic	Data Provider	Variables	Basis of classification	Coverage	Methodology
Clean energy investment	Bloomberg New Energy Finance (BNEF)	Investment, technology area, country	Technology area classified by BNEF	Ten technology areas, investment classified by country receiving investment	Data collected by analysts from public and private sources, such as public announcements of venture capital investment deals
Public research, development, and demonstration (RD&D) in clean energy and related technologies	International Energy Agency (IEA)	Type of RD&D, technology area, country	Technology area classified by IEA	Six broad technology areas and numerous subtechnology areas	Data collected by IEA survey of its member countries
Public and private investment in energy infrastructure	IEA	Investment, type of energy source	Energy source classified by IEA	Six broad and numerous fine technology areas	Data collected by IEA survey of its member countries

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Knowledge and Technology Infrastructure in the World Economy

The first section of this chapter examines the importance of knowledge and technology infrastructure in the global economy. (For an explanation of KTI industries, please see "Chapter Overview.") One key indicator is the KTI industries' share of gross domestic product (GDP) in the global economy, developed economies, and developing economies. (For a discussion of value added and other measures of economic activity, see sidebar, Industry Data and Terminology.) Two critical components of the knowledge and technology infrastructure are education and ICT. Education plays an important role in building human capital for future high-skilled workers employed in KTI and other scientific and KI industries. ICT is regarded as a general-purpose technology that is important for providing the infrastructure for many social and economic activities and for facilitating innovation and economic growth.

The knowledge and technology infrastructure, as measured by the KTI industries' share of global GDP, is a major part of the global economy. KTI industries—commercial KI services, public KI services, and HT manufacturing—make up 29% of world GDP (Figure 6-1; Appendix Table 6-1, Appendix Table 6-2, and Appendix Table 6-3). Among the KTI industries, the commercial KI services—business, financial, and information—have the highest share (17% of GDP) (Appendix Table 6-4). The public KI services—education and health—are the second largest (9%) (Appendix Table 6-3, Appendix Table 6-5, and Appendix Table 6-6).[i] The HT manufacturing industries—aircraft and spacecraft; communications; computers; pharmaceuticals; semiconductors; and testing, measuring, and control instruments—are much smaller, with a 2% share (Appendix Table 6-7).

[i] Data on the health care sector include social services.

Industry Data and Terminology

The data and indicators reported here permit the tracing and analysis of broad patterns and trends that shed light on the spread and shifting distribution of global knowledge- and technology-intensive (KTI) capabilities. The industry data used in this chapter are derived from a proprietary IHS Global Insight database that assembles data from the United Nations (UN) and the Organisation for Economic Co-operation and Development to cover 70 countries consistently. IHS estimates some industry data for developing countries, including China, that are missing or not available on a timely basis.

The industry data follow the International Standard Industrial Classification of All Economic Activities, a UN system for classifying economic activities. Firms are classified according to their primary activity; a company that primarily manufactures pharmaceuticals, for example, but also operates a retail business would have all of its economic activity counted under pharmaceuticals.

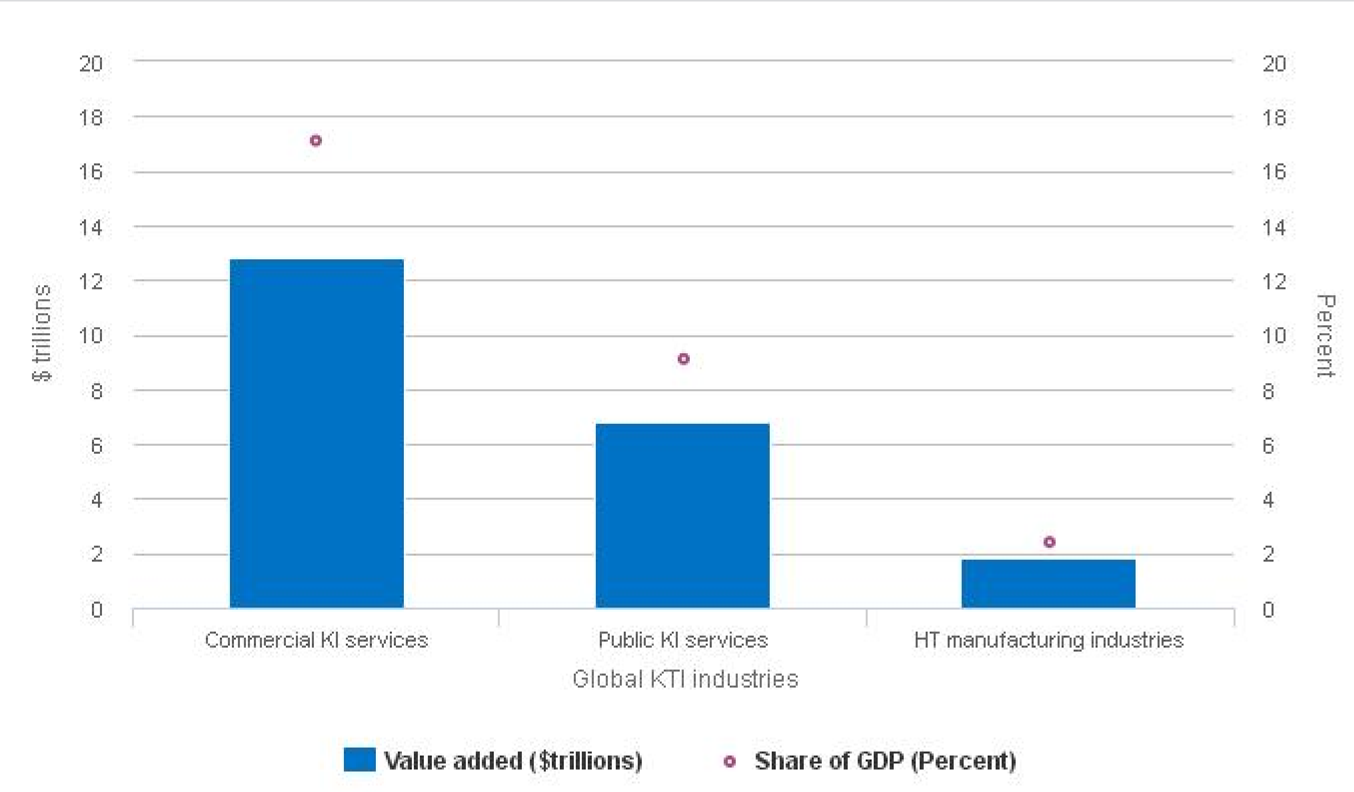
Production is measured as value added. Value added is the amount contributed by an economic entity—country, industry, or firm—to the value of a good or service. It excludes purchases of domestic and imported supplies as well as inputs from other countries, industries, or firms.

Value added is measured in current dollars. For countries outside the United States, value added is recorded in the local currency and converted at the prevailing nominal exchange rate. Industry data are reported in current dollar terms because most KTI industries are globally traded and because most international trade and foreign direct investment is dollar denominated. However, current dollars are an imperfect measure of economic performance. Economic research has found a weak link between nominal exchange rates of countries' currencies that are globally traded and differences in their economic performance (Balke, Ma, and Wohar 2013). In addition, the exchange rates of some countries' currencies are not market determined.

Value added is also an imperfect measure of output. It is credited to countries or regions based on the reported location of the activity, but globalization and the fragmentation of supply chains mean that the precise location of an activity is often uncertain. Companies use different reporting and accounting conventions for crediting and allocating production performed by their subsidiaries in foreign countries. Moreover, the value added from a diversified company's activity is assigned to a single industry based on the industry that accounts for the largest share of the company's business. However, a company classified as manufacturing may include services, and a company classified in a service industry may include manufacturing or may directly serve a manufacturing company. For China and other developing countries, industry data may be estimated by IHS Global Insight or may be revised frequently because of rapid economic change or improvements in data collection by national statistical offices. Thus, value-added trends should be interpreted as broad and relatively internally consistent indicators of the changing distribution of where economic value is generated. Small differences and changes should be treated with caution.

Figure 6-1

Global KTI industries, by output and share of GDP: 2014



GDP = gross domestic product; HT = high technology; KI = knowledge intensive; KTI = knowledge and technology intensive.

NOTES: Output of KTI industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KTI industries include KI services and HT manufacturing industries classified by the Organisation for Economic Co-operation and Development. KI services include business, financial, communications, education, and health. Commercial KI services include business, financial, and communications services. Public KI services include education and health. HT manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-3–6-7.

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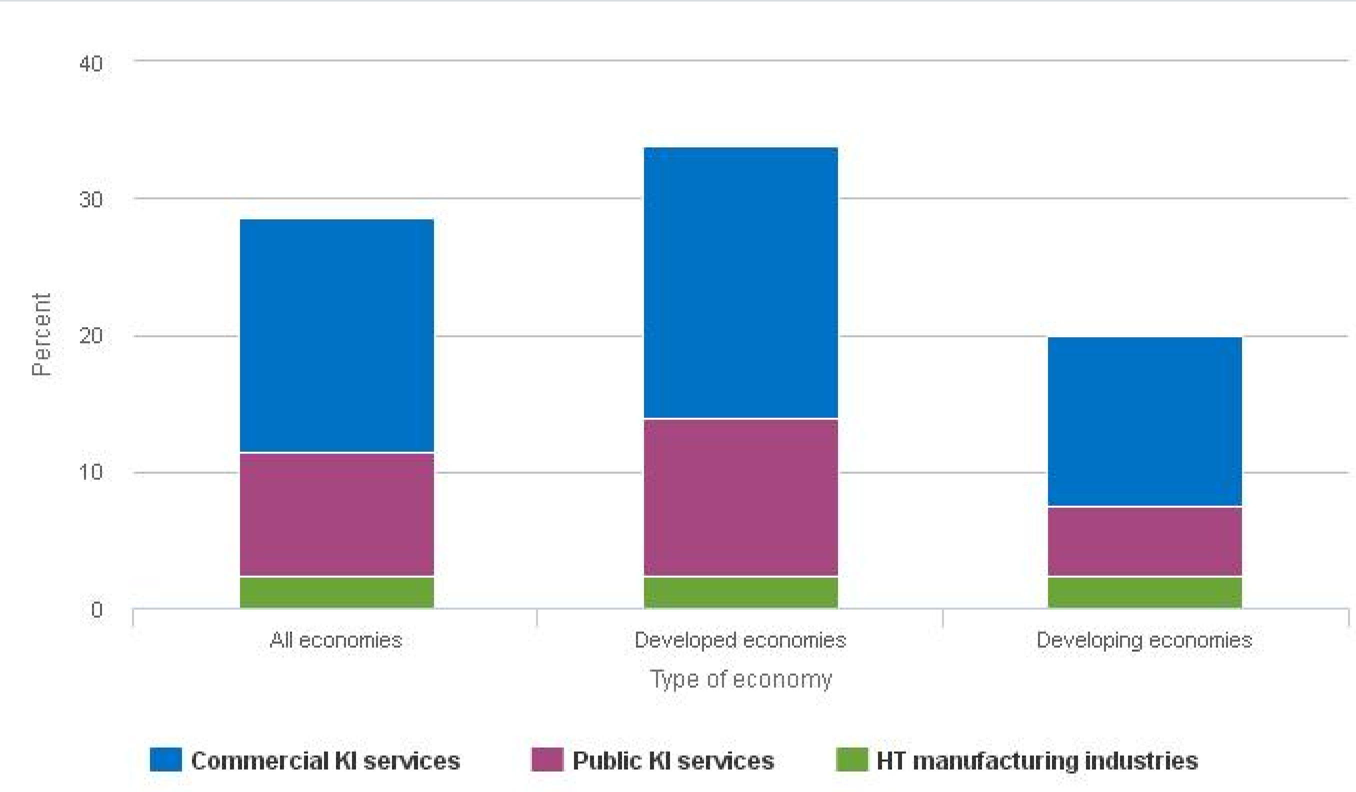
Knowledge- and Technology-Intensive Shares of Economies and Countries

The KTI share of developed economies is much higher than that of developing economies, largely because of their much larger share of KI services (Figure 6-2; Appendix Table 6-2 and Appendix Table 6-3). But KTI shares vary widely, even among developed economies:

Figure 6-2

Selected industry category share of GDP of developed and developing economies: 2014



GDP = gross domestic product; HT = high technology; KI = knowledge intensive.

NOTES: Output of knowledge- and technology-intensive (KTI) industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KTI industries include KI services and HT manufacturing industries classified by the Organisation for Economic Co-operation and Development. KI services include business, financial, communications, education, and health. Commercial KI services include business, financial, and communications services. HT manufacturing industries include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. Public KI services include education and health. Developed economies are those classified as advanced by the International Monetary Fund (IMF). Developing economies are those classified as emerging by IMF.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-3–6-7.

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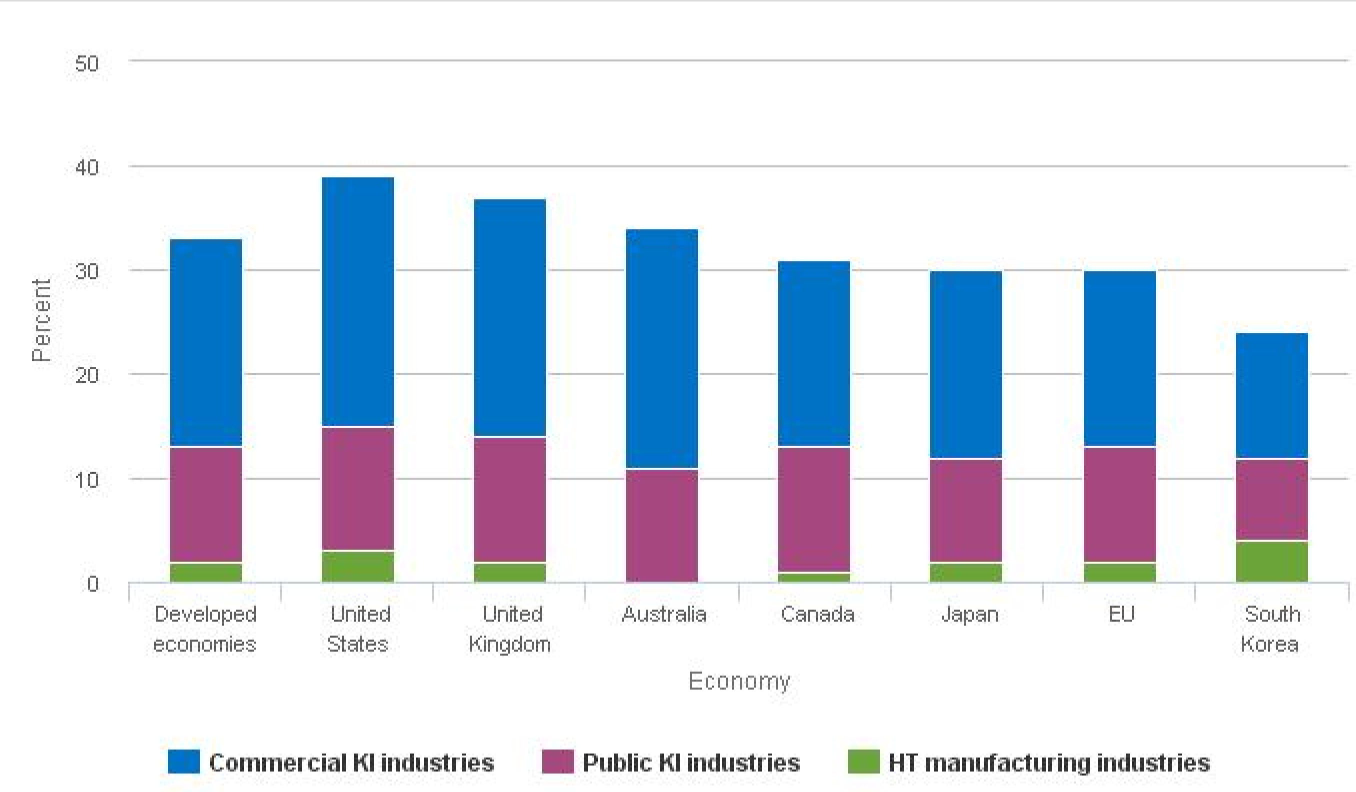
- The KTI shares of the United States (39%) and the United Kingdom (37%) are higher than the average for developed economies (34%) (Figure 6-3), reflecting higher-than-average shares in commercial KI services (23%–24% versus 20% average for developed economies). These two countries have a higher-than-average share of business services (14% versus 11% average for developed economies) (Appendix Table 6-3 and Appendix Table 6-8).
- The EU, Canada, and Japan have KTI shares of 30%–31%, which are close to the average for developed economies. Their shares of commercial KI services (17%–18%) are considerably smaller than that of the United States (24%) (Figure 6-3).
- Spain, Italy, and South Korea have KTI shares below the developed country average.

Figure 6-3

Output of KTI industries as a share of the GDP of selected developed economies: 2014



EU = European Union; GDP = gross domestic product; HT = high technology; KI = knowledge intensive; KTI = knowledge and technology intensive.

NOTES: Output of KTI industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KTI industries include KI industries and HT manufacturing industries classified by the Organisation for Economic Co-operation and Development. KI industries include business, financial, communications, education, and health. Commercial KI industries include business, financial, and communications services. Public KI industries include education and health. HT manufacturing industries include aerospace; communications and semiconductors; computers and office machinery; pharmaceuticals; and testing, measuring, and control instruments. Developed economies are those classified as advanced by the International Monetary Fund.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-3–6-7.

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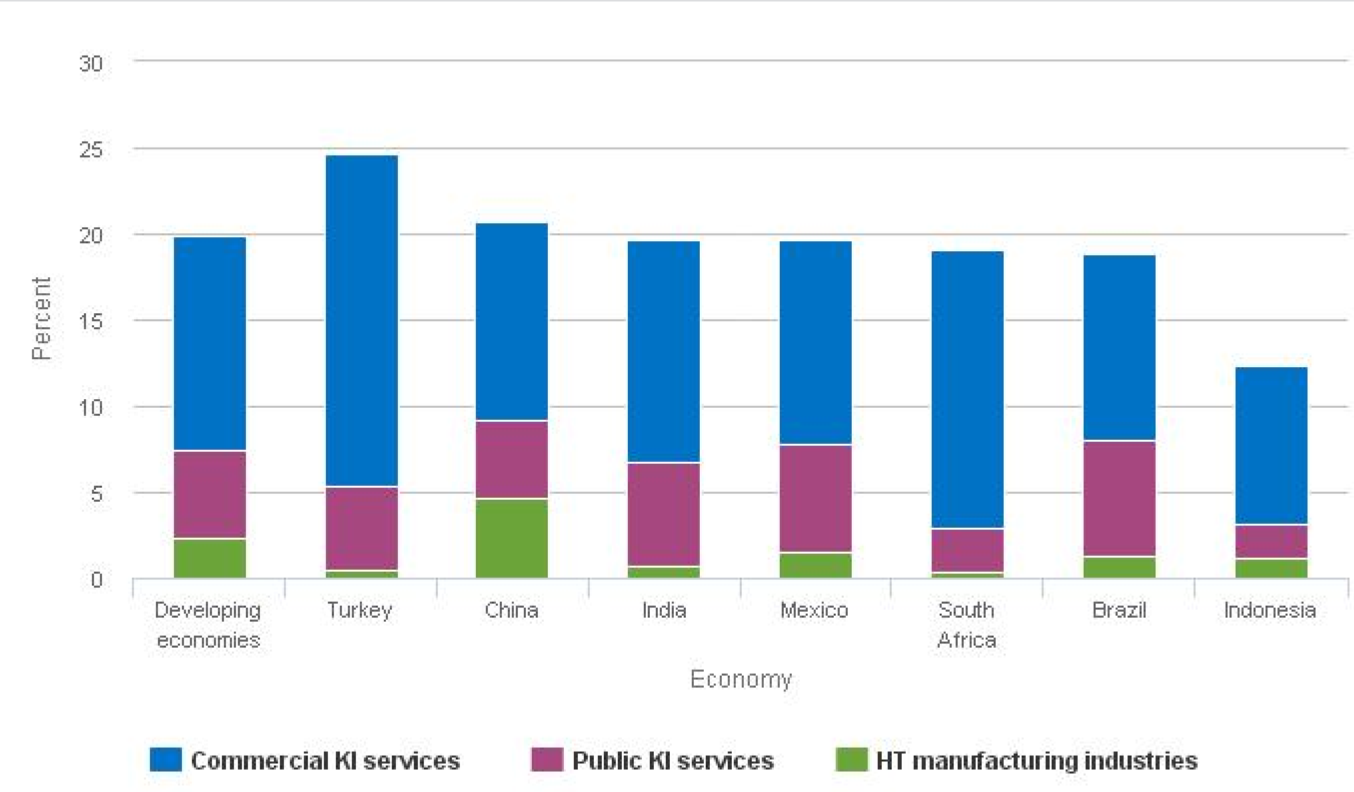
The KTI shares of individual developing countries vary widely, in part reflecting differences in their stage of development and level of per capita income (Figure 6-4; Appendix Table 6-2 and Appendix Table 6-3). Among the larger developing countries, Turkey, with a relatively high per capita income, has the highest KTI share (25%). Five other countries—Brazil, China, India, Mexico, and South Africa—have comparable KTI shares of 19%–21%. Indonesia has the lowest KTI share of any large developing country (12%).

Figure 6-4

Output of KTI industries as a share of GDP of selected developing economies: 2014



GDP = gross domestic product; HT = high technology; KI = knowledge intensive; KTI = knowledge and technology intensive.

NOTES: Output of KTI industries is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KTI industries include KI services and HT manufacturing industries classified by the Organisation for Economic Co-operation and Development. KI services include business, financial, communications, education, and health. Commercial KI services include business, financial, and communications services. Public KI services include education and health. HT manufacturing industries include aerospace; communications and semiconductors; computers and office machinery; pharmaceuticals; and testing, measuring, and control instruments. Developing economies are those classified as emerging by the International Monetary Fund.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-3–6-7.

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Education Infrastructure

Education has long been viewed as an important determinant of economic well-being and development. Research literature suggests that education fosters economic growth through three channels:

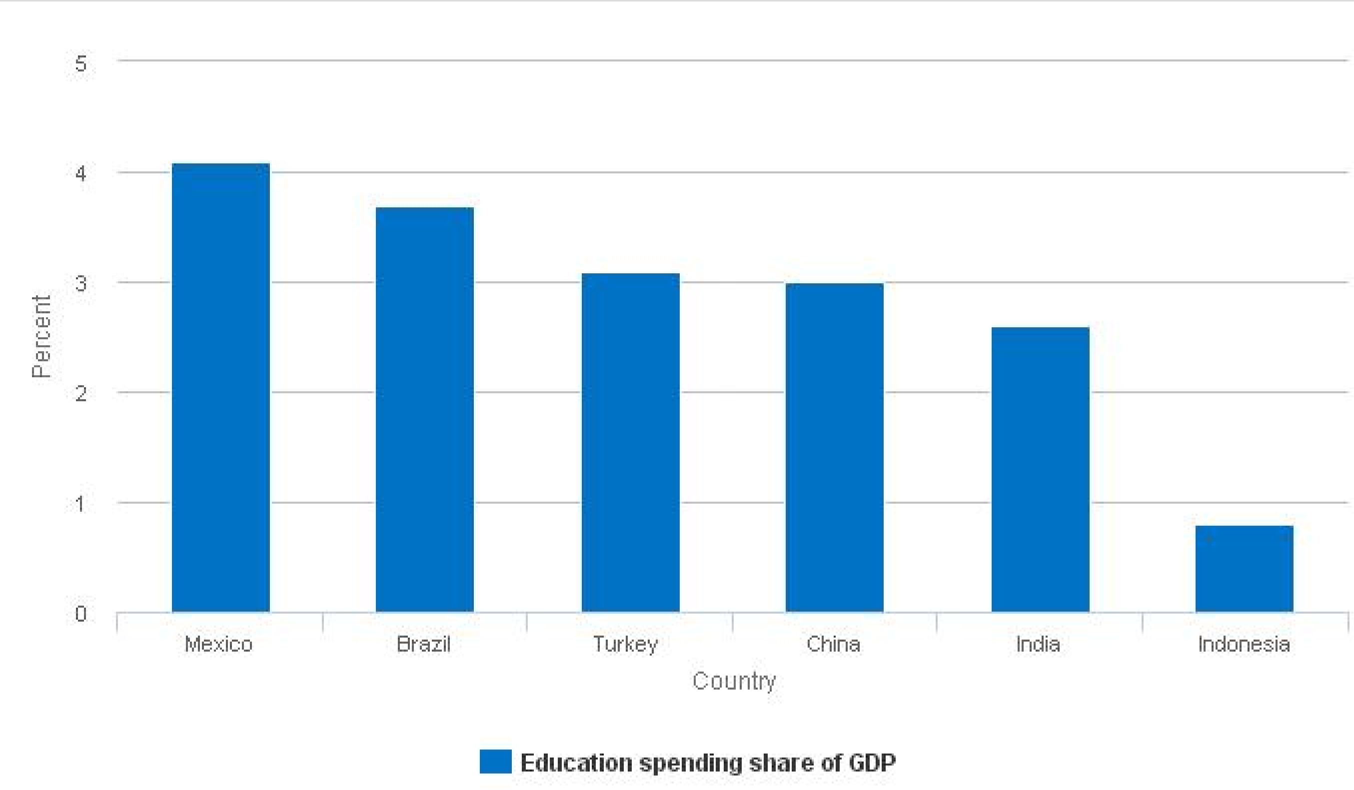
- Raised quality of human capital in the labor force, which lifts labor productivity
- Increased innovative capacity of the economy, which leads to new technologies, products, and processes
- More efficient and effective diffusion and transmission of knowledge needed to understand and process new information and to implement technologies devised by others

This section will examine the education share of GDP, which provides an approximate indication of the size and prominence of the education sector. Chapter 2 has data on international comparisons of S&E degree attainment, an indicator that may be relevant for KTI industries and innovation.

The education spending share of GDP varies widely among the larger developing countries, ranging from 0.8% in Indonesia to 4.1% in Mexico (Figure 6-5). Developed countries also have fairly wide variations in their education spending shares of GDP, ranging from 3.3% in Japan to 5.1% in the United States to 5.7% in the United Kingdom (Figure 6-6).

Figure 6-5

Education spending share of GDP for selected developing countries: 2014



GDP = gross domestic product.

SOURCES: IHS Global Insight, World Industry Service database (2014); World Bank, Education Statistics (2014), http://data.worldbank.org/data-catalog/ed-stats, accessed 15 January 2015. See appendix tables 6-3 and 6-5.

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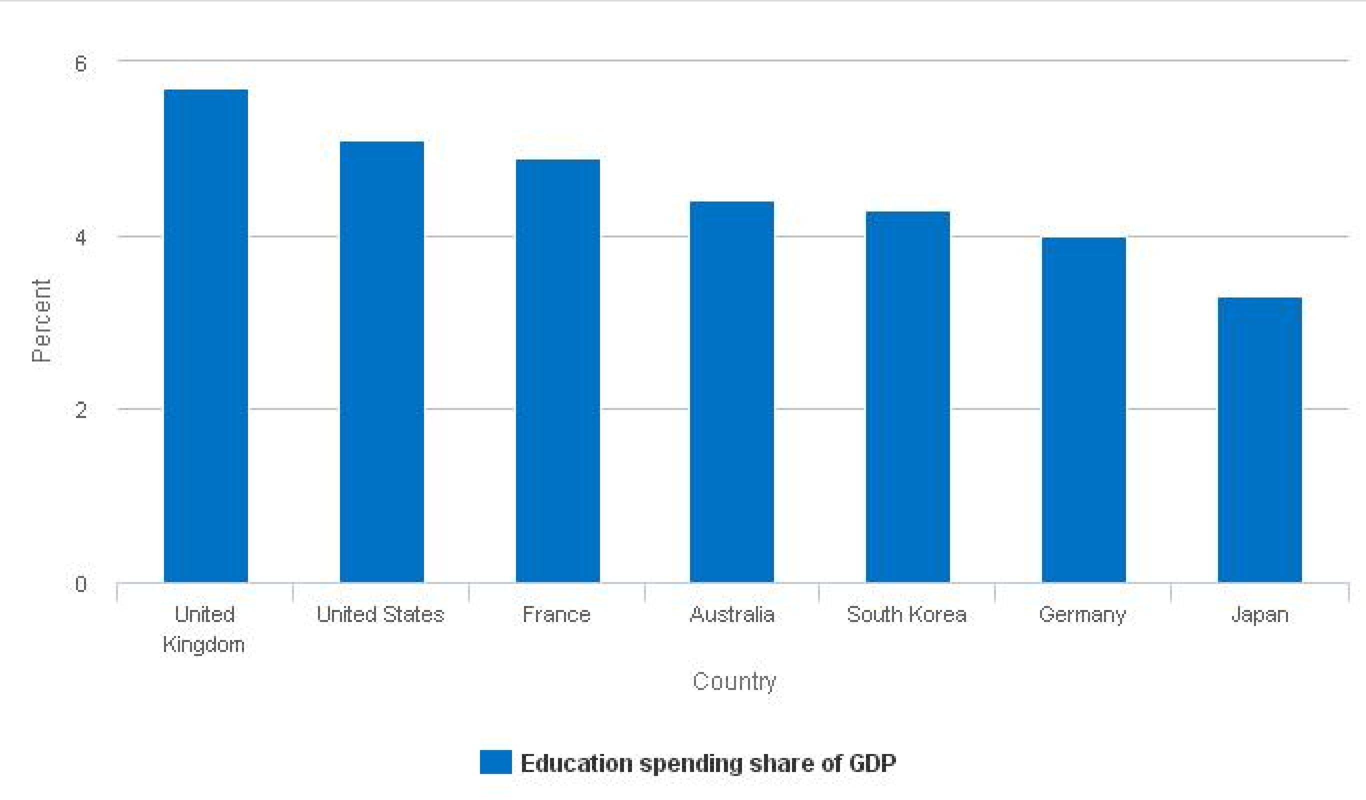
Figure 6-6

Education spending share of GDP for selected developed countries: 2014



GDP = gross domestic product.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-3 and 6-5.

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Information and Communications Technology Infrastructure

Many economists regard ICT as a general-purpose platform technology that fundamentally changes how and where economic activity is carried out in today's knowledge-based countries, much as earlier general-purpose technologies (e.g., the steam engine, automatic machinery) propelled growth during the Industrial Revolution.[i] ICT infrastructure can be as important as or more important than physical infrastructure for raising living standards and economic competitiveness.[ii] This section examines ICT spending by consumers and businesses as a share of GDP.

Among developed countries, the United States, the United Kingdom, Germany, and France have among the highest ICT spending of consumers as a share of their GDP (Figure 6-7). Australia, Japan, and South Korea have slightly lower shares.

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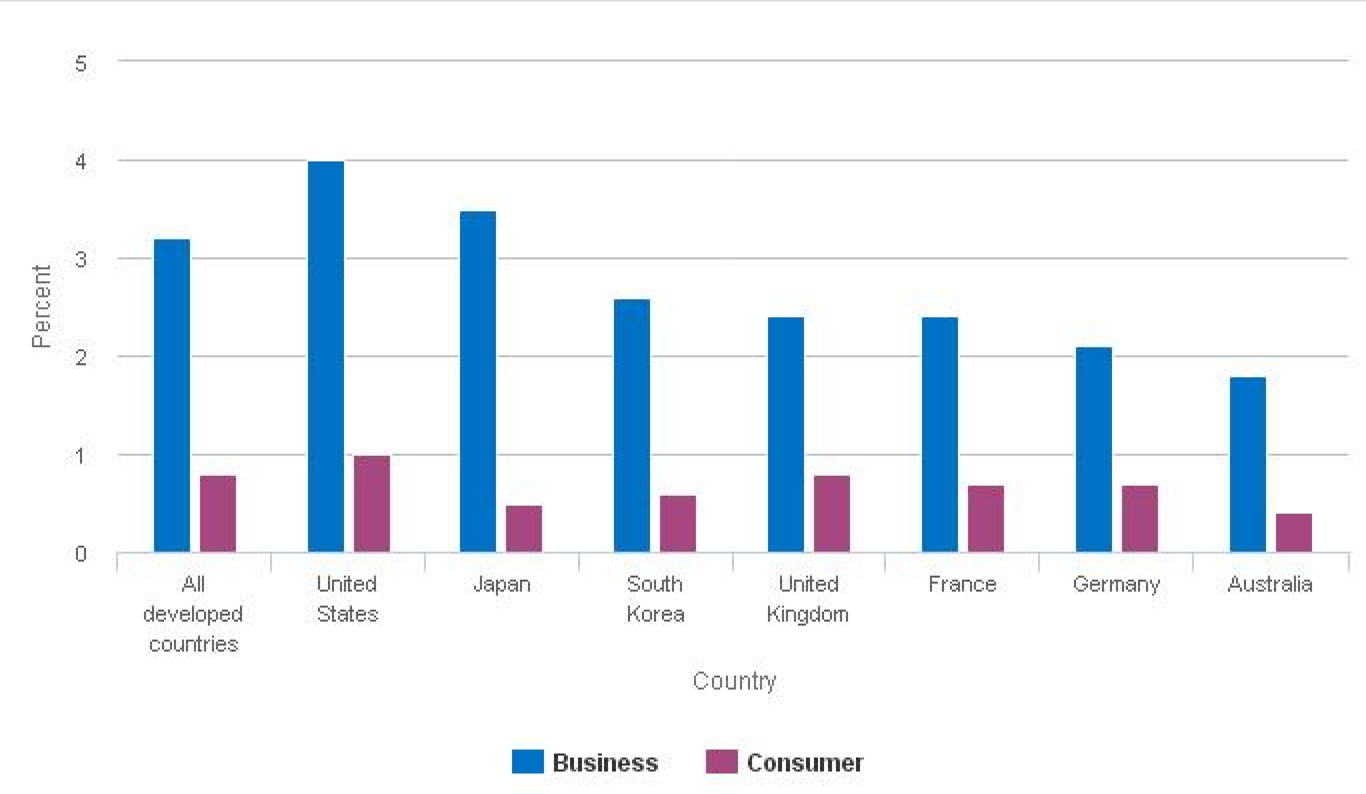
[i] See Bresnahan and Trajtenberg (1995) and DeLong and Summers (2001) for discussions of ICT and general-purpose technologies.

[ii] A World Bank study of developed and developing countries estimated that a 10 percentage point increase in broadband penetration raises economic growth by 1.2–1.4 percentage points (World Bank 2009:45).

Figure 6-7

ICT business and consumer spending as a share of GDP for selected developed countries: 2012–14



GDP = gross domestic product; ICT = information and communications technology.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) from IHS Global Insight ICT Global Navigator.

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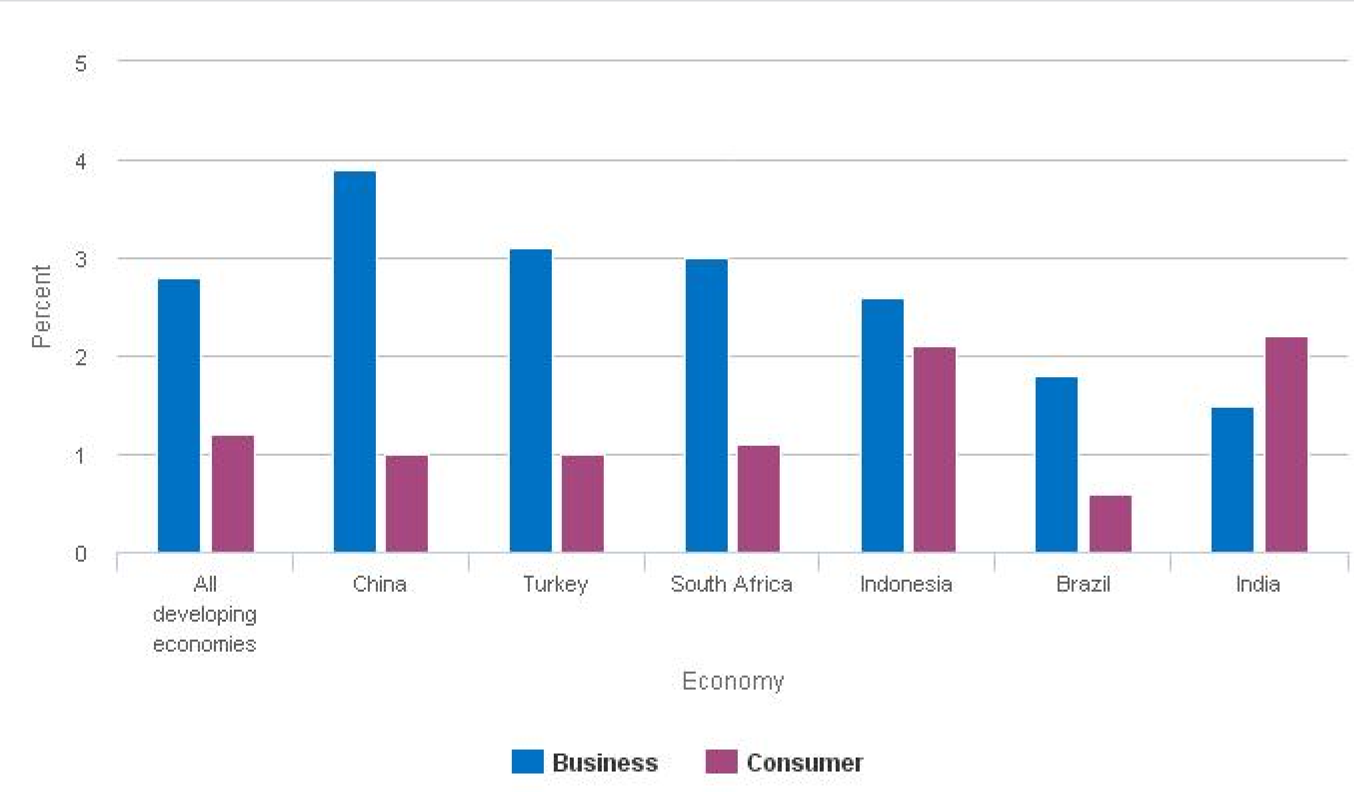
The ICT business spending share is important because of the large impact that businesses have on overall economic growth, employment, and productivity. The United States has the highest share of ICT business spending (4.0%), followed by Japan (3.5%). Australia (1.8%) and Germany (2.1%) have some of the lowest shares in ICT business spending (Figure 6-7).

Many developing countries have ICT spending shares that are comparable with or even higher than those of developed countries (Figure 6-8). China, which leads most of the larger developed economies in the ICT business share, matches the United States in both its ICT business and consumer shares. Turkey, South Africa, and Indonesia have ICT business spending shares between 2.6% and 3.1%.

Figure 6-8

ICT business and consumer spending as a share of GDP for selected developing economies: 2012–14



GDP = gross domestic product; ICT = information and communications technology.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2014) from IHS Global Insight ICT Global Navigator.

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Worldwide Distribution of Knowledge- and Technology-Intensive Industries

This section will examine the positions of the United States and other major economies in KTI industries, as measured by their shares of global KTI activity (Appendix Table 6-1). (For an explanation of KTI industries, please see "Chapter Overview.")

Public Knowledge-Intensive Services Industries

Public KI services—health and education—account for about $7 trillion in global value added (Figure 6-1). These sectors are major sources of knowledge and innovation of great benefit to national economies. Although they are far less market driven than other KTI industries in the global marketplace, competition in education and health appears to be increasing.[i] Education trains students for future work in science, technology, and other fields, and research universities are an important source of knowledge and innovation for other economic sectors. The health sector trains and employs highly skilled workers, conducts research, and generates innovation.

International comparison of both health and education sectors is complicated by variations in the size and distribution of each country's population, market structure, and the degree of government involvement and regulation. As a result, differences in market-generated value added may not accurately reflect differences in the relative value of these services.

The United States and the EU are the world's largest providers of education services, with world spending shares of 28%–30% (Figure 6-9; and Appendix Table 6-5). China is the third-largest provider, followed by Japan. Country and regional shares are similar in health care, except that Japan is ahead of China (Appendix Table 6-6).

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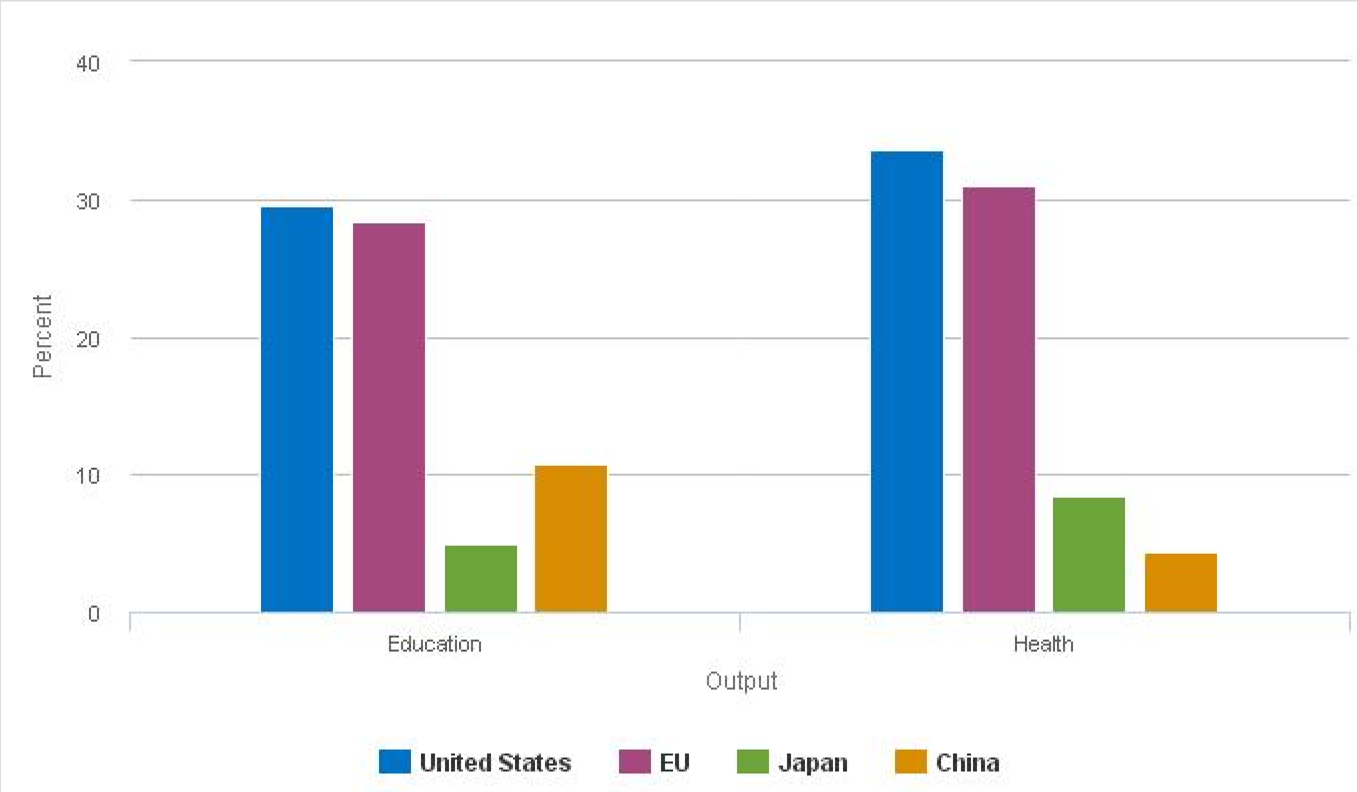
[i] In the education sector, countries compete to attract foreign students to study and train. In the health sector, some countries promote "medical tourism" to attract foreigners to obtain medical care that is often cheaper than that provided in their home country.

Figure 6-9

Output of education and health for selected regions/countries/economies: 2014



EU = European Union.

NOTES: Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Developed countries are those classified as advanced by the International Monetary Fund (IMF). Developing countries are those classified as emerging by IMF.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-5 and 6-6.

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The U.S. and EU global shares of education and health fell modestly between 2003 and 2014 (Appendix Table 6-3, Appendix Table 6-5, and Appendix Table 6-6). Japan's share fell more sharply. China's global share of education and health services more than doubled during this period, in line with its rapid economic growth, emphasis on education, and focused efforts to improve the health care system. Brazil, India, and Indonesia showed a similar expansion in their global shares. The growth of education in China and India coincided with increases in both of these countries in earned higher education degrees and, particularly, doctorates in the natural science and engineering fields (see chapter 2).

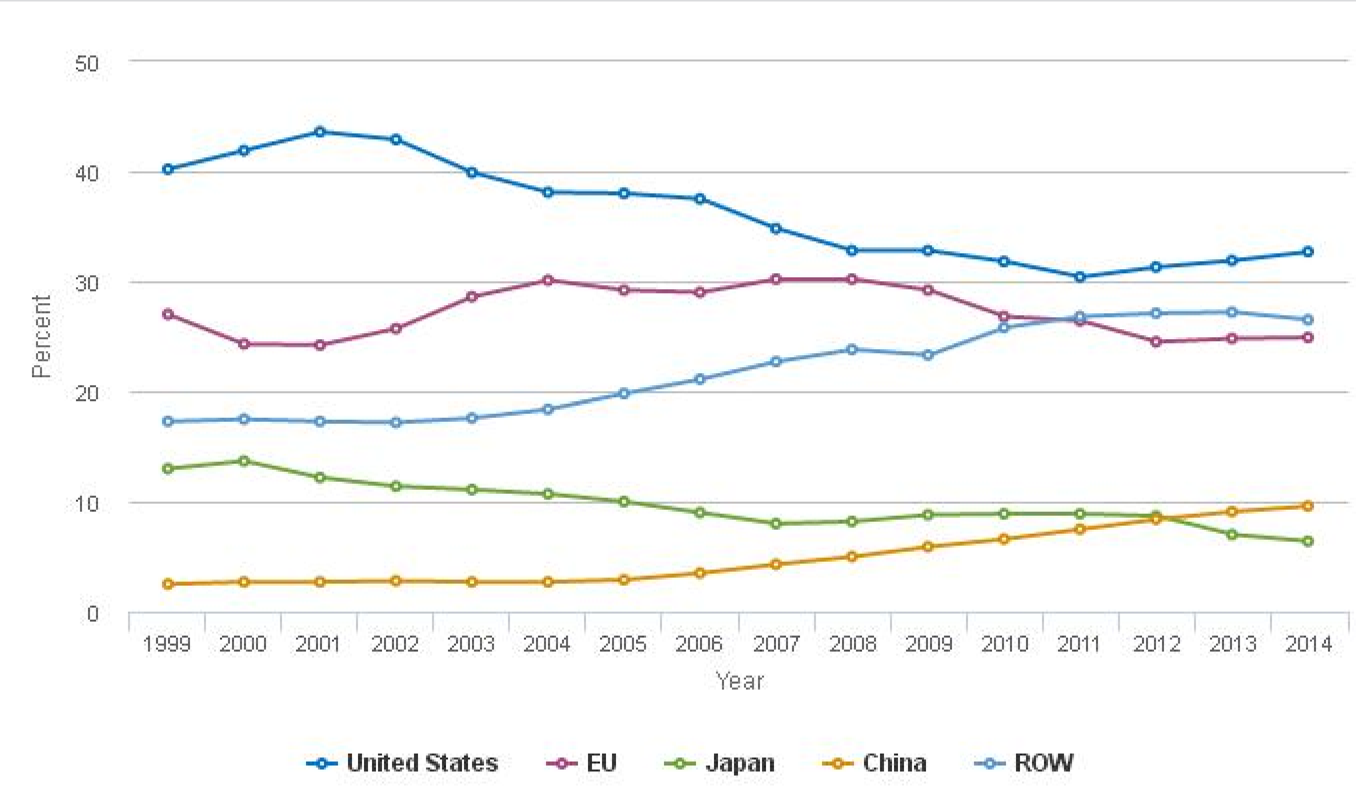
Commercial Knowledge-Intensive Services Industries

The global value added of commercial KI services—business, financial, and information—was $12.7 trillion in 2014 (Figure 6-1; Appendix Table 6-4). Business services, which includes the technologically advanced industries of computer programming and R&D services, is the largest service industry ($6.6 trillion). The large size of business services reflects the widespread practice of businesses and other organizations to purchase various services rather than provide them in-house, particularly in developed countries. The second-largest service industry is financial services ($4.5 trillion), with information far smaller ($1.6 trillion) (Appendix Table 6-8, Appendix Table 6-9, and Appendix Table 6-10).

The United States alone accounted for a third (33%) of global commercial KI services in 2014 (Figure 6-10). U.S. commercial KI services industries employ 19.7 million workers, 14% of the U.S. labor force, and pay higher-than-average wages (Table 6-1; Figure 6-11). In addition, these industries have a much higher concentration of skilled workers as measured by the proportion of those in S&E occupations. These industries perform 29% of U.S. industrial R&D (Table 6-1).

Figure 6-10

Output of commercial KI services for selected regions/countries/economies: 1999–2014



EU = European Union; KI = knowledge intensive; ROW = rest of world.

NOTES: Output of commercial KI services is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Developed countries are those classified as advanced by the International Monetary Fund (IMF). Developing countries are those classified as emerging by IMF.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix table 6-4.

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Table 6-1 Employment and R&D for selected U.S. industries: 2012 or most recent year

Industry	Employment (2014) (millions of jobs)	S&E share	Average salary (actual $)	Business R&D (2013) ($ billions)
All industries	139.0	4.4	45,000	322.5
Commercial KI services	19.7	15.8	68,000	92.5
HT manufacturing	1.8	26.4	70,000	146.7

HT = high technology; KI = knowledge intensive.

NOTES:	Business R&D consists of domestic funding by companies' own internal funds and funds from other sources. Employment consists of the nonagricultural workforce. HT manufacturing industries and KI services are classified by the Organisation for Economic Co-operation and Development. HT manufacturing includes computers, communications, semiconductors, electronic and measuring instruments, aircraft and space vehicles, and pharmaceuticals. KI services include health, education, business, information, and financial services. Commercial KI services include business, information, and financial services. Business R&D of commercial KI services consists of professional and technical services and information. Coverage of some industries may vary among data sources because of differences in classification of industries. Salaries are rounded to the nearest thousand.
SOURCES:	Bureau of Labor Statistics, Current Employment Statistics, http://www.bls.gov/ces/; Bureau of Labor Statistics, Occupational Employment Statistics, special tabulations; National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (2015), http://www.nsf.gov/statistics/srvyindustry/.
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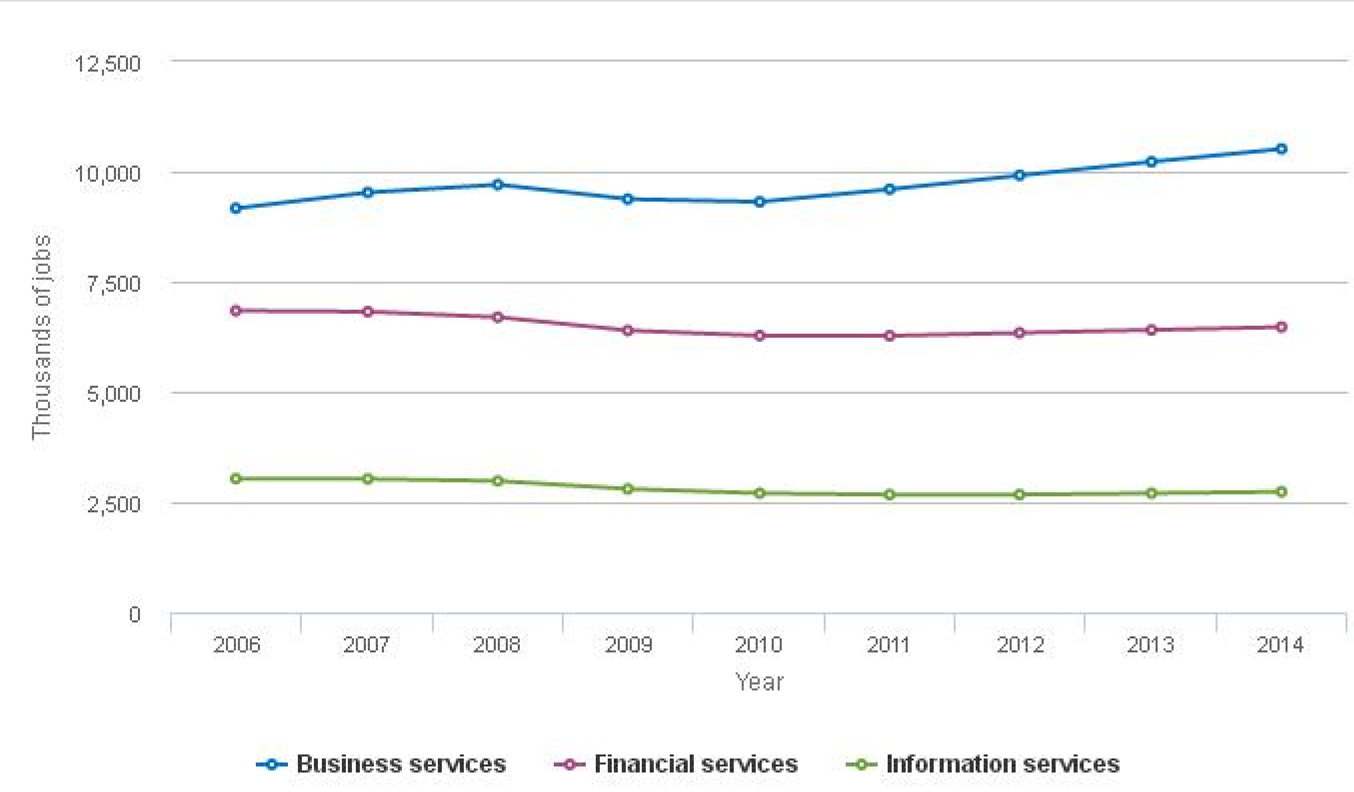
Figure 6-11

U.S. employment in commercial KI services: 2006–14



KI = knowledge intensive.

NOTES: KI services are classified by the Organisation for Economic Co-operation and Development. Commercial KI services include business, financial, and information services. Financial services include finance and insurance and rental and leasing. Business services include professional and technical services and management of companies and enterprises.

SOURCE: Bureau of Labor Statistics, Current Employment Statistics (2014), http://www.bls.gov/ces/, accessed 24 August 2015.

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The EU is the second-largest global provider (25% share) of commercial KI services. China is third (10%) and Japan is fourth (6%) (Figure 6-10).

Trends in Major Economies: U.S. commercial KI services recovered from the global recession bolstered by the strengthening U.S. economy. Value-added output in 2014 was 23% higher than its level in 2008 (Appendix Table 6-4). Business and financial services drove the recovery of commercial KI services, growing 20% and 44%, respectively (Appendix Table 6-8 and Appendix Table 6-9). Output of information services fell slightly (Appendix Table 6-10).

Since 2003, the U.S. global share of commercial KI services has dropped from 40% to less than 31% in 2011 before rising slightly to reach 33% in 2014 (Figure 6-10). These changes have been largely due to much faster growth in China and other developing countries. However, the United States continues to be the dominant provider of commercial KI services. The United States has a particularly strong position in business services (36% global share). Business services led the growth of U.S. commercial KI industries between 2003 and 2014 (Figure 6-12; Appendix Table 6-8). One source of growth of U.S. business services has been the infrastructure boom in developing countries, which has employed U.S. firms in areas including architecture, engineering, and consulting.[i]

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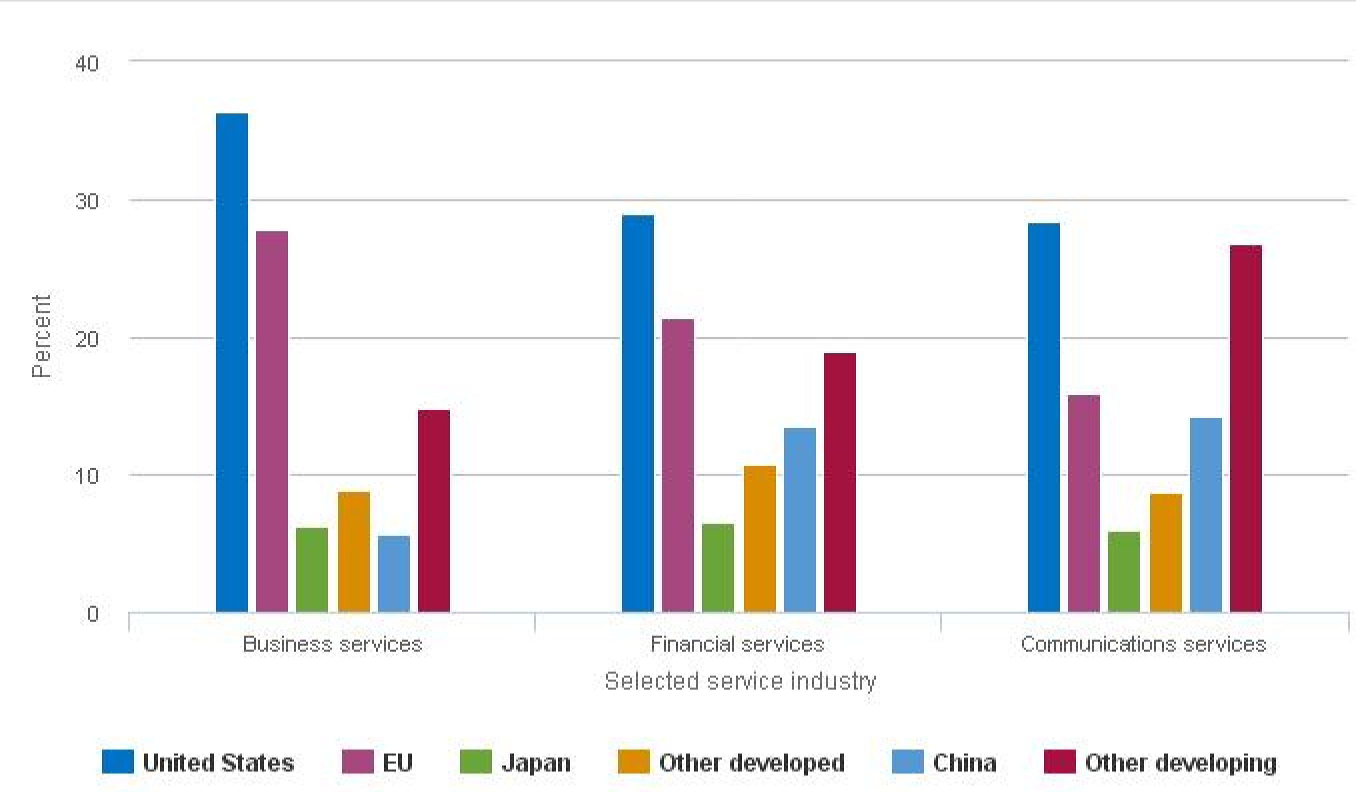
[i] See Jensen (2012) for a discussion of U.S. business services firms helping to build infrastructure in developing countries.

Figure 6-12

Output of selected service industries for selected regions/countries/economies: 2014



EU = European Union.

NOTES: Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. Business services include computer programming, R&D, and other business services. Data on computer programming, a component of business services, are provided separately. Financial services include leasing. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Developed countries are those classified as advanced by the International Monetary Fund (IMF). Developing countries are those classified as emerging by IMF.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-8–6-12.

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Employment in U.S. commercial KI services has had a weak recovery (Figure 6-11), reaching 19.7 million in 2014, a gain of 344,000 jobs over 2008. Business services added about 800,000 jobs, but financial and information services each lost more than 200,000 jobs. The high growth in output of U.S. commercial KI services relative to weak job growth is consistent with historical trends (National Science Foundation, National Center for Science and Engineering Statistics [NSF/NCSES] 2014).

Commercial KI services in the EU have not recovered from the global recession because of member countries' stagnant economies. Output of the EU's commercial KI services was stagnant between 2008 and 2014 in contrast to U.S. industries growing more than 20% (Figure 6-10; Appendix Table 6-4). Commercial KI services in a few EU countries fared better, including Poland (see sidebar, Robust Growth of Poland's Commercial Knowledge-Intensive Services).

Output of Japan's commercial KI services was also flat in the postrecession period (Appendix Table 6-4). Japan's recovery from the global recession has been weak. In addition, Japan's global position has weakened over the last decade because of the lengthy stagnation of the Japanese economy (Figure 6-10).

The modest depreciation of the euro and yen relative to the dollar in 2009–14 may have slightly overstated the weakness of the EU's and Japan's commercial KI services industries (see sidebar, Currency Exchange Rates of Major Economies).

China's commercial KI services rebounded quickly from the global recession with output more than doubling in the postrecession period. China surpassed Japan in 2013 to become the world's third-largest provider (Figure 6-10). Over the last decade, China has grown at an average annual rate of nearly 20%, resulting in its global share more than tripling to reach 10% (Appendix Table 6-4). Business services and financial services led the growth of commercial KI services (Appendix Table 6-8 and Appendix Table 6-9). The rapid growth of financial services reflects the substantial role of public-owned or public-supported financial institutions.

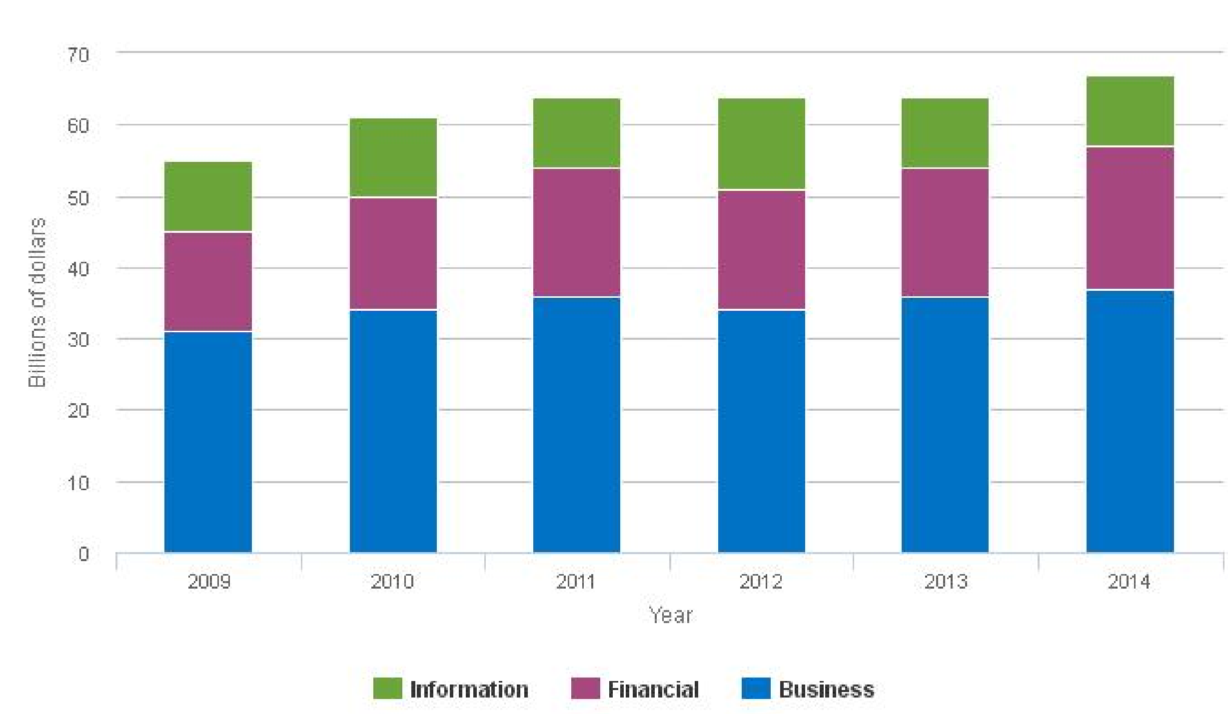
The developing economies of Brazil, India, and Russia also had sizable gains in commercial KI services, with each reaching global shares of 2% (Appendix Table 6-4). Brazil's expansion was led by financial services and information (Appendix Table 6-9 and Appendix Table 6-10). India gained the most in business services, particularly in computer programming, reflecting, in part, the success of Indian firms providing information technology (IT), accounting, legal, and other services to developed countries (Appendix Table 6-8 and Appendix Table 6-12). Russia's gain occurred from growth in its business and financial services.

Robust Growth of Poland's Commercial Knowledge-Intensive Services

Poland, a newer member of the EU, has sidestepped many of its neighbors' recent financial and economic difficulties. Poland's stable and growing economy has been attributed to its not adopting the euro and to its relatively low wage levels. Poland's service sector has grown rapidly over the last decade, with commercial KI services expanding from \$56 billion in 2009 to \$67 billion in 2014 (Figure 6-A). Business services have grown the fastest among the commercial KI services, reaching \$37 billion in 2014. Outsourcing is a major and growing component of business services. Many foreign firms, including Infosys, have established sites in Poland that perform back office work such as finance and information technology for major corporations. Outsourcing companies are attracted to Poland's well educated and often multilingual work force. The business services industry is estimated to employ 110,000 workers, nearly as much as its automotive industry (140,000) (Ewing 2013).

Figure 6-A

Output of commercial KI services industries of Poland: 2009–14



KI = knowledge intensive.

NOTES: Output is on a value-added basis. Value added is the amount contributed by a country, firm, or entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-15–6-20.

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Currency Exchange Rates of Major Economies

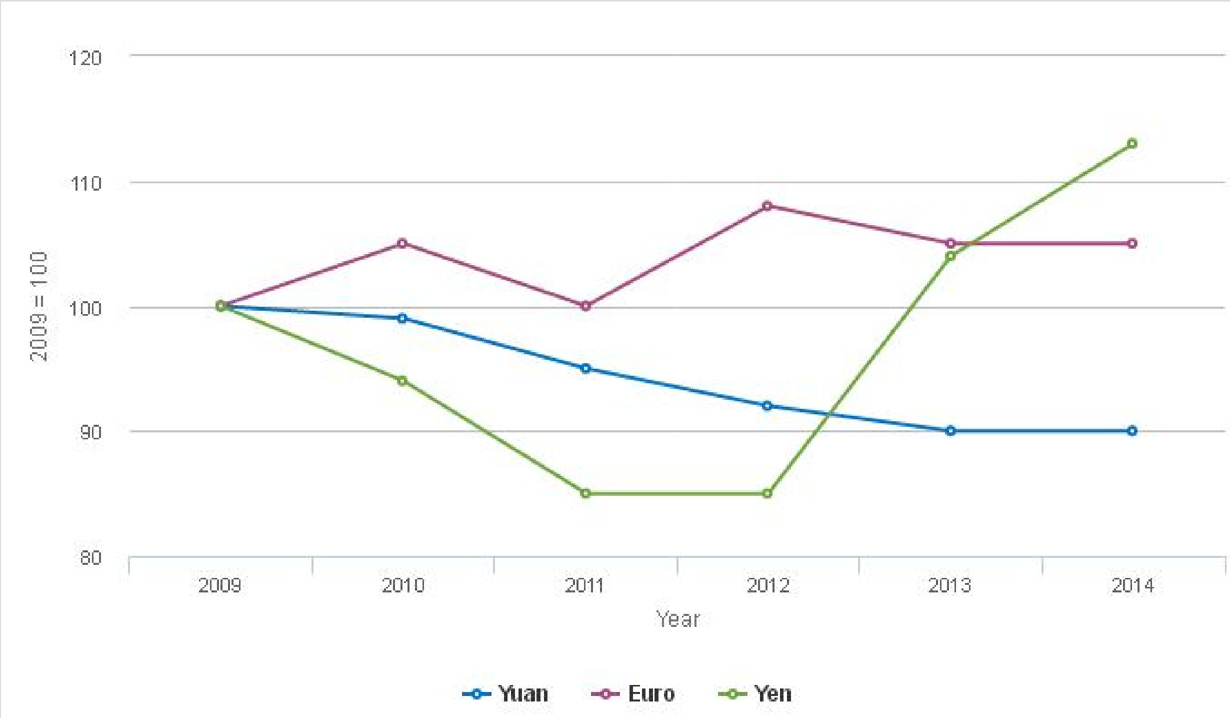
International comparisons of industry, trade, investment, and other global economic activities often use current dollars at market exchange rates. Most global economic activities are dollar denominated, which facilitates comparison. In addition, many economists believe that market exchange rates reflect, at least to some degree, differences in economic performance among various countries (Balke, Ma, and Wohar 2013:2).

However, fluctuations in exchange rates may also reflect factors other than economic performance. Governments can and do take action to influence the level of their exchange rates, ranging from intervening in currency exchange markets so as to exercise almost complete control of rates to using macroeconomic policies and other mechanisms so as to exercise more limited and indirect influence on markets. In addition, factors such as political instability or the short-term effects of global financial events on a country's economy can cause currency fluctuations that are unrelated to enduring differences in national economic performance. Factors such as these should remind the reader that comparing economic data from different countries in current dollar terms provides a mostly broadly indicative but rarely precise reflection of a country's relative economic performance.

Between 2009 and 2014, the exchange rates of the world's four largest economies—China, the EU member countries that use the euro (the eurozone), Japan, and the United States—exhibited some fluctuations (Figure 6-B). The euro and Japanese yen depreciated 5% and 13%, respectively, against the dollar. The yuan's exchange rate, which is controlled by China's government, modestly appreciated against the dollar.

Figure 6-B

U.S. dollar exchange rate with selected currencies: 2009–14



SOURCE: Federal Reserve, Economic and Research and Data, Foreign Exchange Rates, http://www.federalreserve.gov/releases/h10/current/, accessed 15 February 2015.

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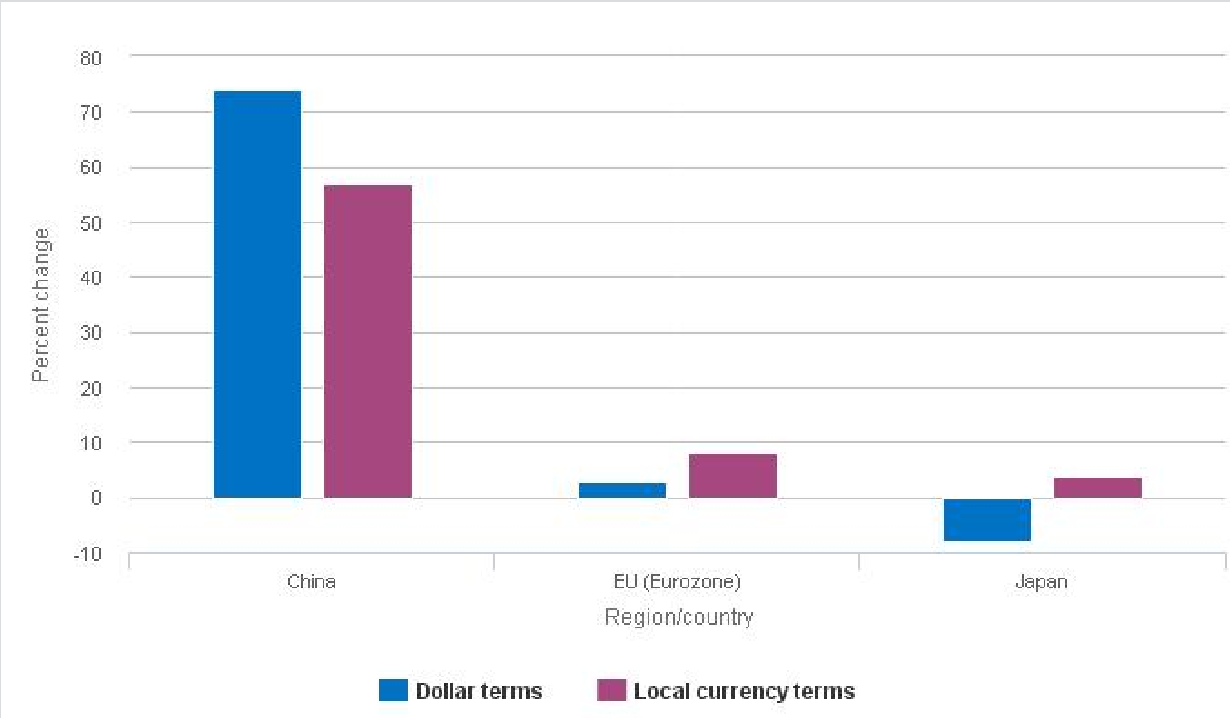
The depreciation of the euro and yen against the dollar from 2009 to 2014 made the eurozone's and Japan's positions in economic activities—denominated in current U.S. dollars—appear somewhat weaker during this period. Denominated in local currency terms, their economic performance looked stronger. For example, the value added of Japan's commercial KI services in current dollars declined 8% from 2009 to 2014 (Figure 6-C). The value added in yen increased 4%. The EU's commercial KI services increased 3% in dollar terms and 8% on a euro basis.

Figure 6-C

Output of commercial KI services industries, by selected region/country/economy: 2009–14



EU = European Union; KI = knowledge intensive.

NOTES: Output of commercial KI services is on a value-added basis. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. KI services include education, health, and business, financial, and communications services and are classified by Organisation for Economic Co-operation and Development. Commercial KI services consist of financial services, information, and business. EU (Eurozone) consists of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Slovakia, Spain, and Sweden.

SOURCES: Federal Reserve, Economic Research and Data, Foreign Exchange Rates, http://www.federalreserve.gov /releases/h10/current/, accessed 15 February 2015; IHS Global Insight, World Industry Service database (2014). See appendix table 6-7.

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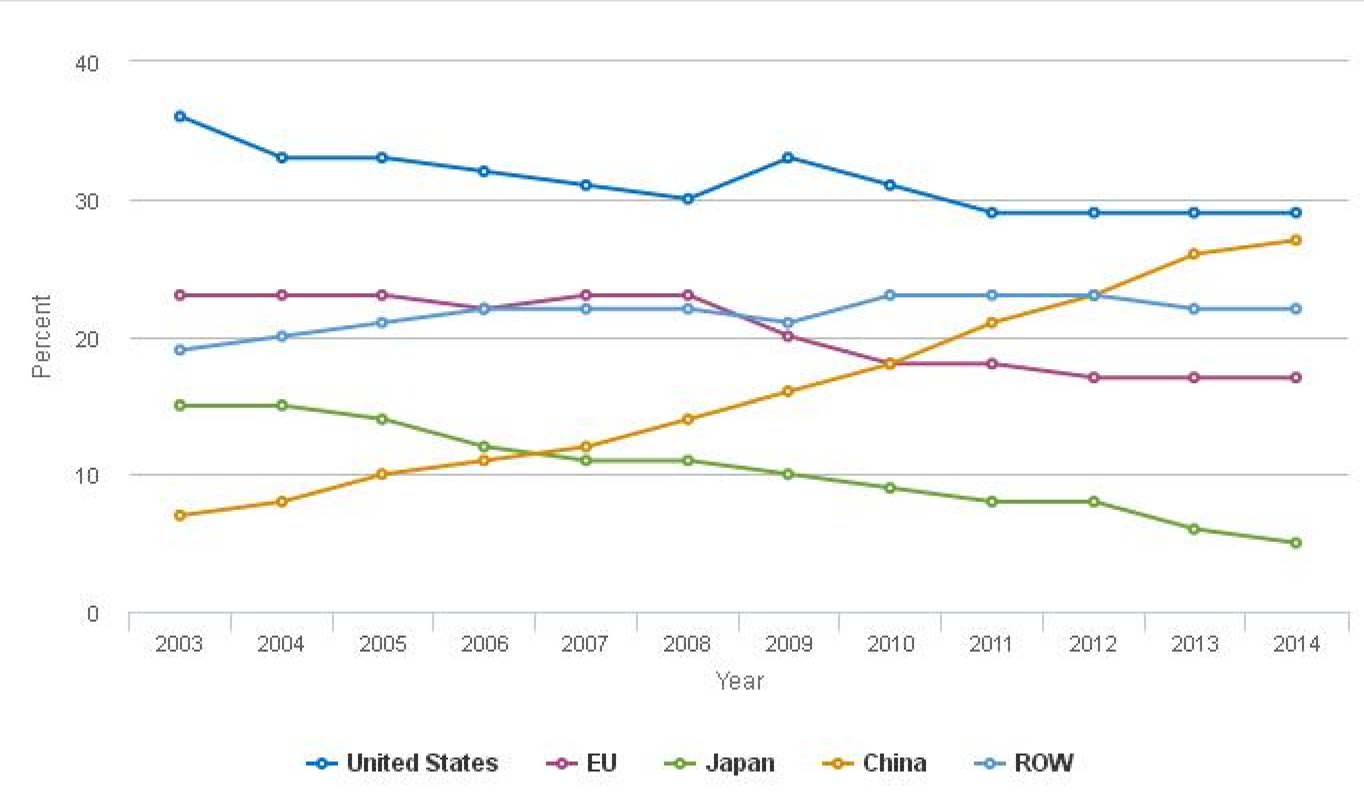
High-Technology Manufacturing Industries

Global value added of HT manufacturing was $1.8 trillion in 2014, making up 15% of the manufacturing sector (Figure 6-1; Appendix Table 6-7 and Appendix Table 6-11). The three ICT manufacturing industries—semiconductors, computers, and communications—made up a collective $0.7 trillion in global value added (Appendix Table 6-13, Appendix Table 6-14, and Appendix Table 6-15). The three remaining industries are pharmaceuticals ($500 billion); testing, measuring, and control instruments ($360 billion); and aircraft and spacecraft ($200 billion) (Appendix Table 6-16, Appendix Table 6-17, and Appendix Table 6-18).

The United States and China are the largest global producers (29% and 27% global share, respectively) (Figure 6-13) of HT manufacturing industries. U.S. HT manufacturing industries employ 1.8 million workers and pay higher-than-average wages due, in part, to their high concentration of highly skilled S&E workers (Table 6-1; Figure 6-14). Although a small part of the U.S. economy (3% of GDP), U.S. HT manufacturing industries fund about one-half of U.S. business R&D.

Figure 6-13

Output of HT manufacturing industries for selected regions/countries/economies: 2003–14



EU = European Union; HT = high technology; ROW = rest of world.

NOTES: Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. HT manufacturing industries are classified by the Organisation for Economic Co-operation and Development and include aircraft and spacecraft; communications; computers; pharmaceuticals; semiconductors; and testing, measuring, and control instruments. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong. Developed countries are those classified as advanced by the International Monetary Fund (IMF). Developing countries are those classified as emerging by IMF.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix table 6-7.

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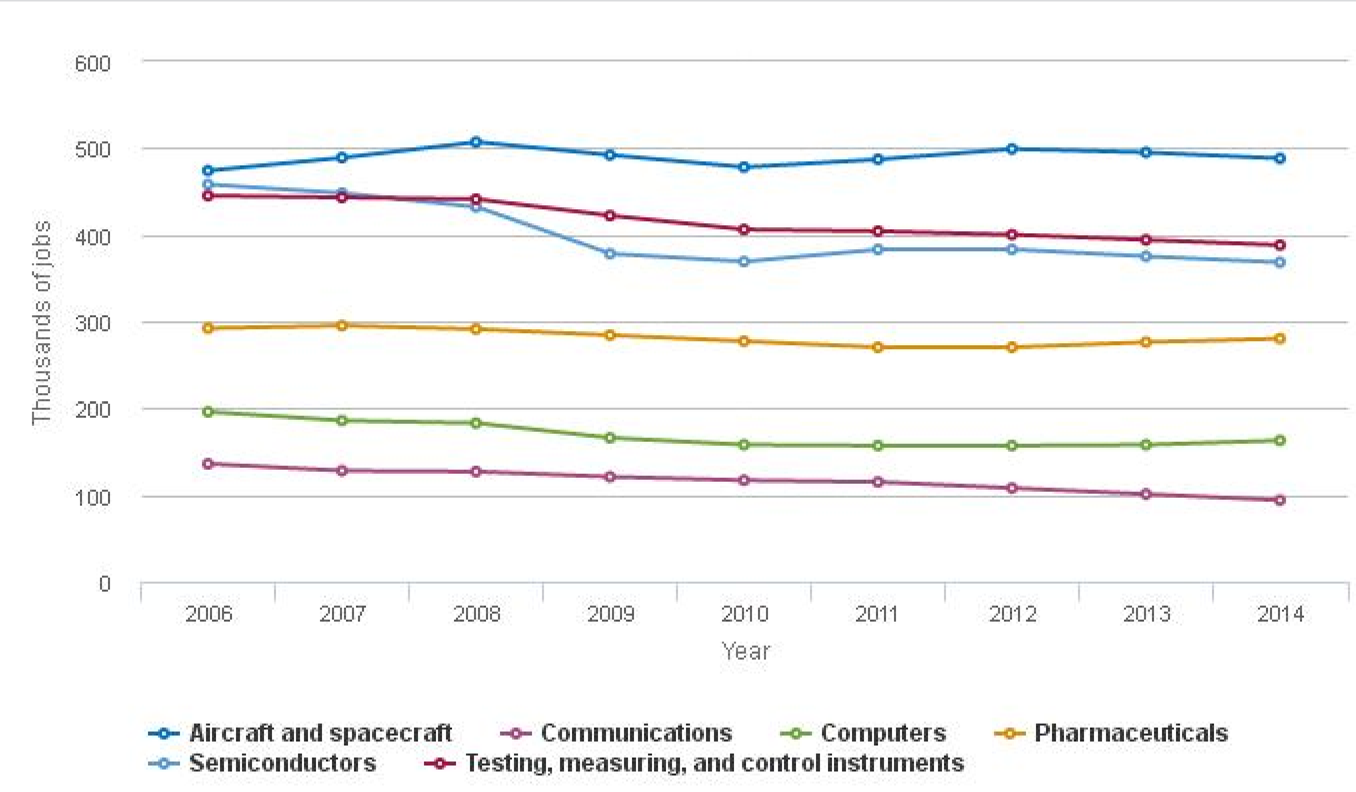
Figure 6-14

U.S. employment in HT manufacturing industries: 2006–14



HT = high technology.

NOTES: HT manufacturing industries are classified by the Organisation for Economic Co-operation and Development. HT manufacturing industries include aircraft and spacecraft; communications; computers; pharmaceuticals; semiconductors; and testing, measuring, and control instruments.

SOURCE: Bureau of Labor Statistics, Current Employment Statistics (2014), http://www.bls.gov/ces/, accessed 15 February 2015.

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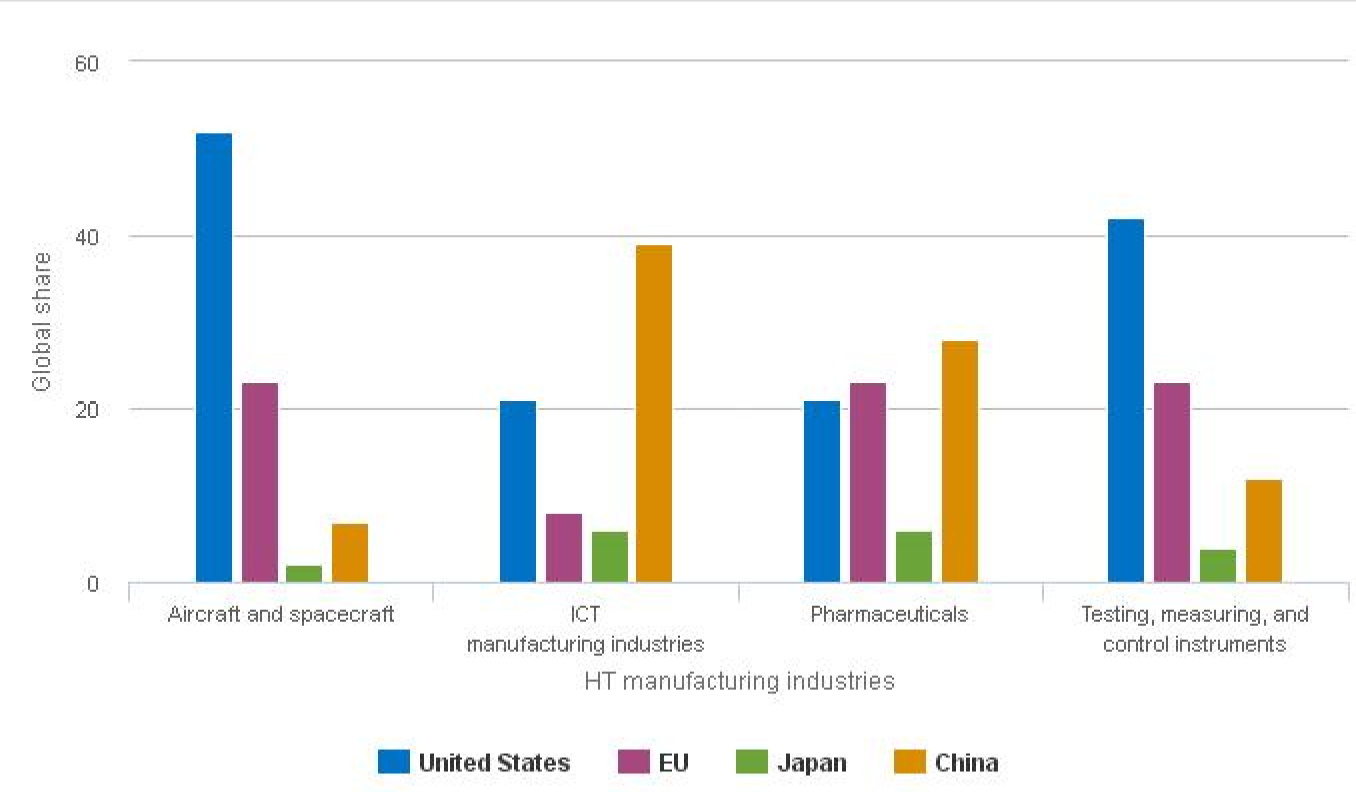
China is the largest global producer of the ICT manufacturing industries (39% global share), functioning as the final assembly location for these goods produced in "Factory Asia"—the electronics goods production network centered in East Asia (World Trade Organization and Institute of Developing Economies 2011:14–15) (Figure 6-15).

Figure 6-15

HT manufacturing industries of selected regions/countries/economies: 2014



EU = European Union; HT = high technology; ICT = information and communications technology.

NOTES: HT manufacturing industries are classified by the Organisation for Economic Co-operation and Development and include aircraft and spacecraft; communications; computers; pharmaceuticals; semiconductors; and testing, measuring, and control instruments. ICT manufacturing industries consist of computers, communications, and semiconductors. Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Developed countries are those classified as advanced by the International Monetary Fund (IMF). Developing countries are those classified as emerging by IMF.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-20 and 6-27–6-33.

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The EU and Japan are the third- and fourth-largest global producers with shares of 17% and 5%, respectively (Figure 6-13; Appendix Table 6-7).

Trends of the United States

U.S. HT manufacturing has recovered from the global recession with the strengthening U.S. economy. In 2014, U.S. HT manufacturing output was 18% higher than in 2008 (Appendix Table 6-7). Four HT manufacturing industries have driven postrecession growth: semiconductors; pharmaceuticals; testing, measuring, and control instruments; and aircraft and spacecraft (Appendix Table 6-13 and Appendix Table 6-16, Appendix Table 6-17, and Appendix Table 6-18). The United States continues to have a dominant position in aircraft (52% global share) and testing, measuring, and control instruments (42%).

Over the last decade, the U.S. global share of HT manufacturing has slipped from 33% to level off at 29% starting in 2011, largely due to much faster growth in China. Despite the decline in the U.S. global share, U.S. HT manufacturing output grew by more than 40% over the last decade. The four industries that led the postrecession recovery have also been the drivers of growth over the last decade (Appendix Table 6-13 and Appendix Table 6-16, Appendix Table 6-17, and Appendix Table 6-18). Growth of the ICT manufacturing industries of computers and communications has been stagnant because of the relocation of final production to China and other countries and the intensification of global competition (Appendix Table 6-14 and Appendix Table 6-15).

Despite a recovery in output, U.S. employment in HT manufacturing has not increased. Employment fell from 2.0 million jobs in 2008 to 1.8 million in 2014 (Figure 6-14). The lack of employment growth reflects the relocation of production to China and other countries, as well as the rapid productivity growth of U.S. HT manufacturing industries, which have eliminated some jobs, particularly those in routine tasks (see sidebar, U.S. Manufacturing and Employment). Some researchers and policymakers have concluded that the location of HT manufacturing and R&D activities may lead to the migration of higher-value activities abroad (Fuchs and Kirchain 2010:2344).

Trends of Other Major Producers

HT manufacturing industries in the EU and Japan have not recovered from the global recession. In the EU, output contracted by 7% between 2008 and 2014 because of the EU's weak economy. Because of the EU's lack of growth, its global share slipped from 23% to 17% during this period (Appendix Table 6-7). Among individual industries, the output of the ICT manufacturing industries shrank by a third. Pharmaceuticals grew slightly (5%), and aircraft and spacecraft grew by 16% (Appendix Table 6-16 and Appendix Table 6-18).

Japan's HT manufacturing industries contracted by 41% between 2008 and 2014 because of its weak recovery from the global recession. In addition, Japan's deep decline is likely due to its decade-long stagnant economy, the loss of competitiveness of Japanese electronics firms, and the transfer of production to China and other countries (Appendix Table 6-7). Over the last decade, value-added output contracted by 44%, resulting in Japan's global share dropping from 15% to 5%. Output of ICT industries alone fell by more than half.

After output growth slowed greatly in 2009 during the global recession, China's HT manufacturing industries rebounded strongly. China's value-added output in 2014 was more than double its level in 2008 (Appendix Table 6-7). Over the last decade, value-added output rose more than fivefold, pushing China's global share from 8% to 27%. China's rapid gain has been attributed to many factors, including policies and subsidies to encourage MNCs to invest in China, low wages, adequate infrastructure, and the global scale of China's manufacturing plants.

China became the world's largest producer in the ICT manufacturing industries with a 39% global share in 2014 (Figure 6-15; Appendix Table 6-13, Appendix Table 6-14, and Appendix Table 6-15). China also became the world's largest producer of pharmaceuticals, with a 28% share (Appendix Table 6-16), helped by production of generic drugs by China-based firms and the establishment of production facilities controlled by U.S. and EU multinationals. Output has grown rapidly in testing, measuring, and control instruments, although from a low base (Appendix Table 6-17).

Notwithstanding these rapid advances, HT manufacturing in China continues to be limited to lower value-added activities, such as final assembly.[i] For example, although Chinese semiconductor companies have gained global market share, China remains very reliant on semiconductors supplied by foreign firms for most of its production of smartphones and other electronic products (PricewaterhouseCoopers 2014). Many MNCs continue to conduct their higher value-added activities in developed countries because of the greater availability of skilled workers and stronger intellectual property protection. In addition, Chinese-owned HT companies have not met many of the ambitious targets and goals of the Chinese government's indigenous innovation program.

Anecdotal reports suggest that some multinationals are relocating their facilities from China to other developing countries with lower labor costs or returning production to developed countries in response to increases in transportation costs and in China's manufacturing wages.[ii] However, China remains an attractive location for foreign MNCs because of its well-developed manufacturing infrastructure that can supply the global market. In addition, China's growing and potentially huge domestic market is prompting some foreign HT firms to expand their production facilities and establish R&D laboratories to develop products for China's rapidly growing consumer market.

Other major Asian producers—Singapore, South Korea, and Taiwan—showed little change in their global shares during this period (Appendix Table 6-7). Over the last decade, companies based in these economies have moved up the value chain to become producers of semiconductors and other sophisticated components that are supplied to China and other countries.

Other Asian countries that grew rapidly include the Philippines and Vietnam (Appendix Table 6-7) (see sidebar, High-Technology Manufacturing Industries Take Off in the Philippines).

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[i] See Williamson and Raman (2011) for a discussion of China's acquisition of foreign companies.

[ii] See *Economist* (2013) for a discussion of multinational firms choosing to have more of their manufacturing take place in developed countries.

U.S. Manufacturing and Employment

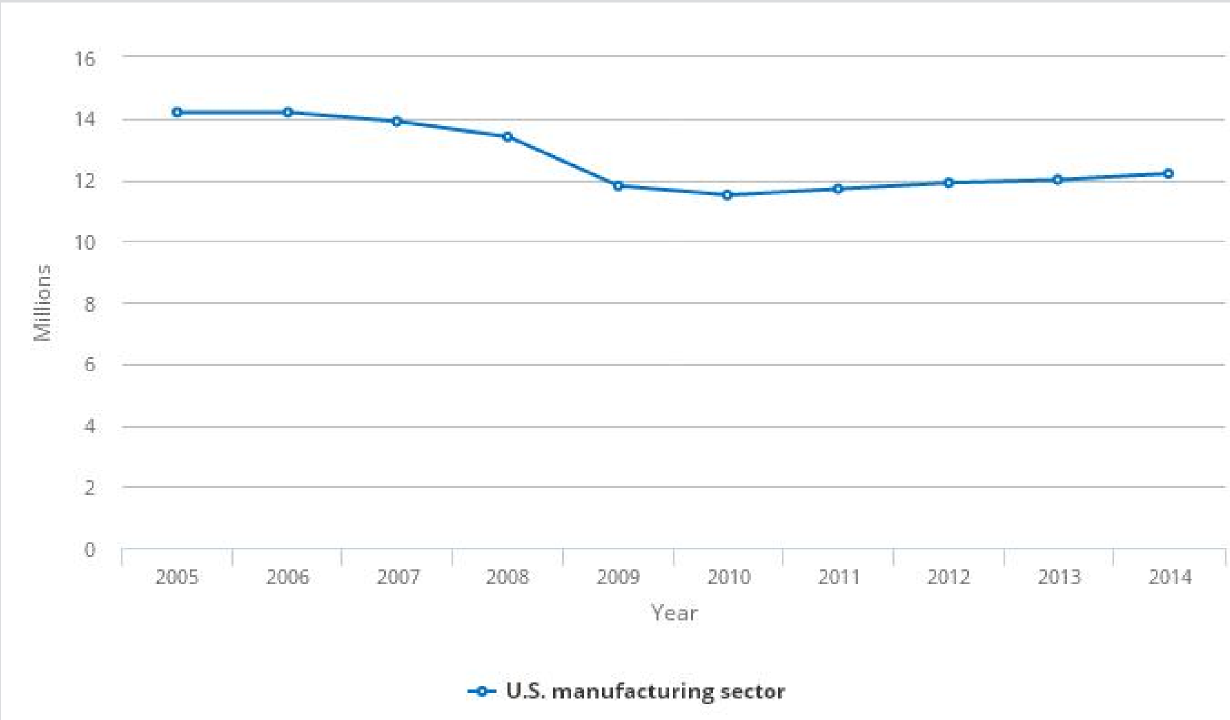
Several signs point to an increase in U.S. manufacturing activity after years of decline. After falling continuously in the previous decade, employment in the U.S. manufacturing sector increased somewhat in 2011–14, coinciding with a rebound in this sector's output after the 2008–09 global recession (Figure 6-D). However, employment in 2014 remains well below its pre-recession level. According to press reports, several firms, including Apple, General Electric, and Lenovo, are building new manufacturing facilities in the United States (Booth 2013:1). Some analysts and researchers predict a resurgence in U.S. manufacturing production, pointing to low transportation and energy costs, modest U.S. labor costs, and favorable currency exchange rates as factors conducive to manufacturing growth (PricewaterhouseCoopers 2012:3).

However, others doubt that there will be a large-scale relocation of manufacturing facilities in the United States or installation of new facilities. Even if there is significant increase in manufacturing production from relocation or new plants, some doubt that this will be accompanied by large-scale increases in employment. Many U.S. manufacturing industries are highly productive, which allows them to increase output substantially without increasing employment much. Although manufacturers in the United States and other high-income economies will continue to hire more high-skilled workers, manufacturing employment is likely to continue to decline over the next several decades due to further advances in productivity and global competitive pressures (McKinsey Global Institute 2012:4).

In interpreting recent trends in manufacturing production and employment, it is helpful to take into account that manufacturing's share of gross domestic product and the labor force has steadily declined in the United States and other advanced countries over the past several decades (Shipp et al. 2012:61). Even as its share of output and employment has declined, manufacturing continues to play a key role in innovation, productivity, and exports in developed countries.

Figure 6-D

U.S. manufacturing employment: 2005–14



SOURCE: U.S. Bureau of Labor Statistics, Current Employment Statistics, http://www.bls.gov/ces/.

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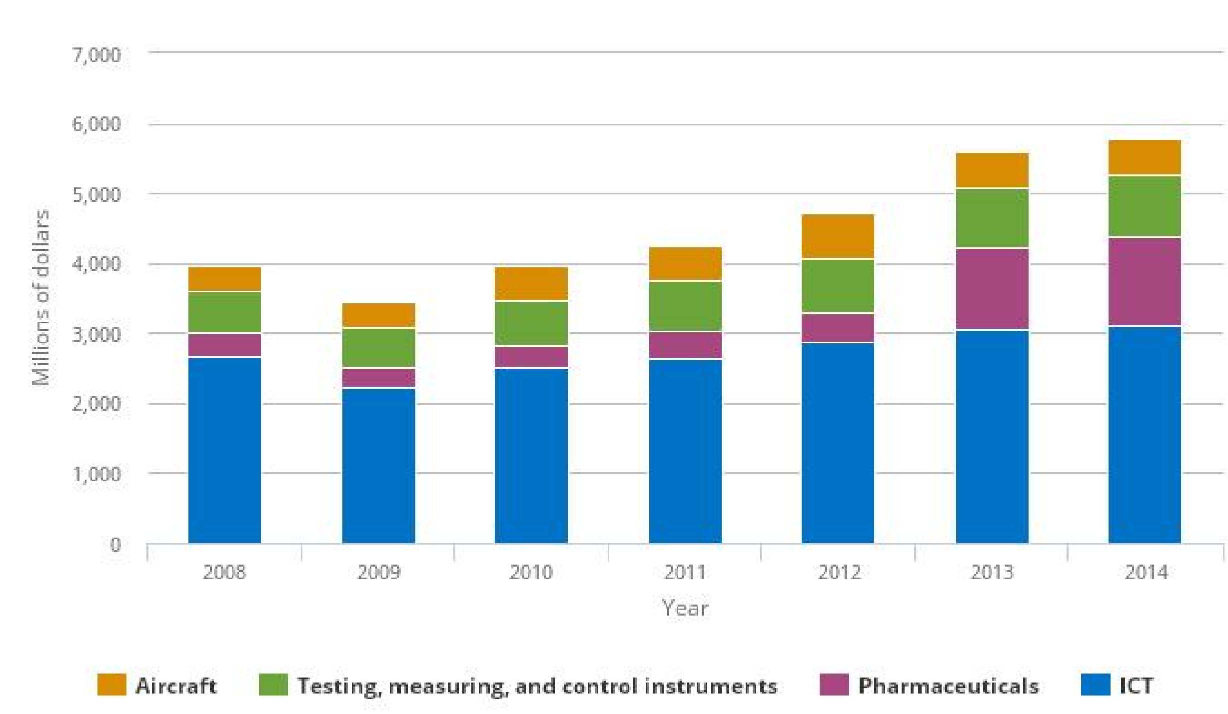
High-Technology Manufacturing Industries Take Off in the Philippines

The Philippines is a rapidly growing emerging economy that is transitioning from being primarily based on agriculture to being based more on services and trade. The value added of the Philippines' HT manufacturing industries expanded from $4.0 billion in 2008 to $5.8 billion in 2014, largely due to gains in communication goods and pharmaceuticals (Figure 6-E). The Philippines' market for pharmaceuticals is growing quickly because of rapid growing demand for health care, domestic manufacturing capability, and extensive involvement of foreign pharmaceutical companies. Multinationals have chosen to invest in the Philippines to capitalize on the growing domestic market and to use the Philippines as a launching pad into other Southeast Asian markets. Most multinationals import or distribute their finished drug products or outsource their production to local manufacturers. Production of communication goods has also risen rapidly because the Philippines has become a substantial producer of finished goods and supplier of intermediate inputs to "Factory Asia," the production network of electronics in East Asian countries (World Trade Organization and Institute of Developing Economies 2011:14–15).

Figure 6-E

HT manufacturing output of the Philippines: 2008–14



HT = high technology; ICT = information and communications technologies.

NOTES: Output is on a value-added basis. Value added is the amount contributed by a country, firm, or entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. ICT manufacturing industries consist of communications, computers, and semiconductors.

SOURCE: IHS Global Insight, World Industry Service database (2014). See appendix tables 6-15–6-20.

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Trade and Other Globalization Indicators

The third section of this chapter examines several trade and globalization measures associated with KTI industries in the United States and other economies. (For an explanation of KTI industries, please see Chapter Overview.) In the modern world economy, production is more often *globalized* (i.e., value is added to a product or service in more than one nation) and less often *vertically integrated* (i.e., conducted under the auspices of a single company and its subsidiaries) than in the past. These trends have affected all industries, but their impact has been pronounced in many commercial KTI industries. The broader context is the rapid expansion of these industrial and service capabilities in many developing countries, both for export and internal consumption, accompanied by an increasing supply of skilled, internationally mobile workers. (See Chapter 3 for a discussion on the migration of highly skilled labor.)

This section focuses on cross-border trade of international KI services and HT trade. It also examines direct investment and other globalization measures of U.S. multinationals in KTI industries. Trade data are a useful though imperfect indicator of globalization (for a discussion, see sidebar, Measurement and Limitations of Trade Data).

This discussion of trade trends in KI services and HT manufactured products focuses on (1) the trading zones of the North American Free Trade Agreement (NAFTA), with a particular focus on the United States, and the EU; (2) China, which is rapidly taking on an increasingly important role in KTI trade; (3) Japan and other Asian economies; and (4) large developing countries, including Brazil and India.

The EU, East Asia, and NAFTA have substantial volumes of intraregional trade. This section treats trade within these three regions in different ways. Intra-EU and NAFTA exports are not counted because they are integrated trading zones with common external trade tariffs and few restrictions on intraregional trade. This kind of trade is treated as essentially equivalent to trade between China and Hong Kong, which is excluded because it is essentially intra-economy trade. (Data on trade in commercial KI services between China and Hong Kong are not available.) Intra-Asian trade is counted for other Asian countries because they have a far smaller degree of political and trade integration.

Measurement and Limitations of Trade Data

Trade data are based on a classification of goods or services themselves, rather than industry sectors. In the case of product trade, trade is assigned one product code according to the Harmonized Commodity Description and Coding System, or Harmonized System (HS).* The product classification of trade is fundamentally different from the industry classification used in the last section, which is based on the primary activity of the industry that produced a product and not on the characteristics of the product itself. Thus, the two classifications cannot be mapped onto each other. For example, an export classified as a computer service in the product-based system may be considered computer manufacturing in the industrial classification because it originated from a firm in that industry.

Data on exports and imports represent the market value of products and services in international trade. Exports of products are assigned by the importing country’s port of entry to a single country of origin. For goods manufactured in multiple countries, the country of origin is determined by where the product was “substantially transformed” into its final form.

The value of product trade entering or exiting a country's ports may include the value of components, inputs, or services classified in different product categories or originating from countries other than the country of origin. For example, China is credited with the full value (i.e., factory price plus shipping cost) of a smartphone when it is assembled in China, though made with components imported from other countries. In these data, countries whose firms provide high-value services such as design, marketing, and software development are typically not credited for these contributions.

* HS is used to classify goods traded internationally and was developed under the auspices of the Customs Co-operation Council. Beginning on 1 January 1989, HS numbers replaced schedules previously adhered to in more than 50 countries, including the United States. For more information, see http://www.census.gov/foreign-trade/guide/sec2.html#htsusa.

Global Trade in Commercial Knowledge- and Technology-Intensive Goods and Services

Exported goods and services to other countries are one measure of a country's economic success in the global market because exports capture the country's products that compete in the world market. In addition, exports bring in income from external sources and do not consume the income of a nation's own residents.

Global trade in commercial KTI goods and services consists of four services—communications, computer and information, finance, and other business—and six HT products—aerospace; communications; computers; pharmaceuticals; semiconductors; and testing, measuring, and control instruments.[i] Global cross-border exports of commercial KTI goods and services were an estimated $4.0 trillion, consisting of $1.6 trillion of commercial KI services and $2.4 trillion of exports of HT products (Appendix Table 6-19, and Appendix Table 6-20).

Commercial Knowledge-Intensive Services

Global exports of commercial KI services make up 44% of all commercial services. The commercial KI services share of services exports has risen from 38% to 44% during the last decade, a rise that coincided with the growth of companies contracting these services to companies in other countries. Among the commercial KI services, the largest was other business services, which include R&D services, architectural, engineering, and other technical services ($944 billion). The other three services are finance (which includes insurance) ($321 billion), computer and information services ($192 billion), and communications ($86 billion) (Appendix Table 6-21, Appendix Table 6-22, Appendix Table 6-23, and Appendix Table 6-24).

The EU was the largest exporter of commercial KI services, with a global share of 31% in 2013 (Figure 6-16). The United States was the second largest at 17%. Both had surpluses in trade of commercial KI services, in contrast to their deficits in HT product trade (Table 6-2).[ii] China and India, tying for third place, each had a 7% global export share (Table 6-3; Figure 6-16). India had a substantial surplus in trade of commercial KI services.

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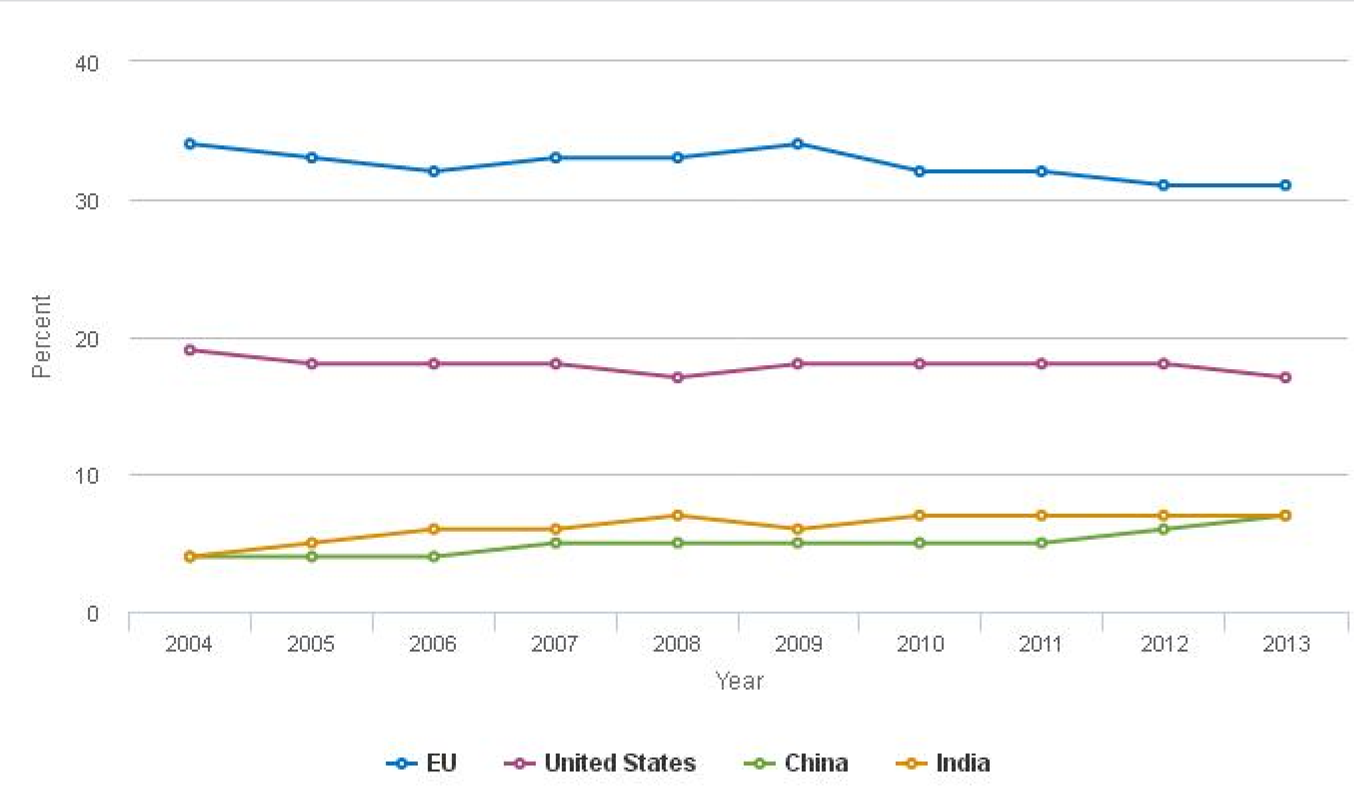
[i] Other business services includes trade-related services, operational leasing (rentals), and miscellaneous business; professional and technical services such as legal, accounting, management consulting, public relations services, advertising, market research and public opinion polling; R&D services; architectural, engineering, and other technical services; and agricultural, mining, and on-site processing.

[ii] A trade surplus occurs when exports exceed imports. A trade deficit occurs when imports exceed exports.

Figure 6-16

Commercial KI service exports, by selected region/country/economy: 2004–13



EU = European Union; KI = knowledge intensive.

NOTES: Commercial KI service exports consist of communications, business services, financial services, and computer and information services. Financial services includes finance and insurance services. EU exports do not include intra-EU exports.

SOURCE: World Trade Organization, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 February 2015.

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Table 6-2 U.S. and EU commercial KI services trade, by category: 2013

(Billions of dollars)

	United States			EU		
Category	Exports	Imports	Balance	Exports	Imports	Balance
United States						
All commercial KI services	270.8	196.4	74.4	482.4	288.9	193.5
Computer and information services	18.2	26.3	-8.1	62.5	25.9	36.6
Financial services	99.5	68.5	31.0	103.9	41.3	62.6
Other business services	138.2	93.0	45.2	283.9	195.9	88.0

	United States			EU		
Category	Exports	Imports	Balance	Exports	Imports	Balance
Communications services	14.8	8.6	6.2	32.0	25.7	6.3

NOTES: EU = European Union; KI = knowledge intensive.
Commercial KI services trade consists of communications, other business services, financial services, and computer and information services. Financial services includes finance and insurance. EU trade does not include intra-EU trade.

SOURCE: World Trade Organization, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 February 2015.

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Table 6-3 India's and China's trade in commercial KI services: 2013

(Billions of dollars)

	India			China		
Category	Exports	Imports	Balance	Exports	Imports	Balance
All commercial KI services	111	43	67.5	104	81	23.0
Communications services	2.2	1.1	1.1	1.7	1.6	0.1
Computer information services	50	3	46.9	15	6	9.5
Financial services	8	11	-3.4	7	26	-18.6
Other business services	50.9	28.0	23.0	79.5	47.5	32.0

NOTES: KI = knowledge intensive.
Commercial KI services trade consists of communications, business services, financial services, computer and information services, and other business services. Financial services includes finance and insurance.

SOURCE: World Trade Organization, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 February 2015.

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Trends of major exporters. From 2004 to 2013, the EU's exports of commercial KI services more than doubled to $482 billion (Table 6-2; Appendix Table 6-19). This was driven by growth of other business services exports (Appendix Table 6-24). The EU's trade surplus widened in all major components of commercial KI services.

Over the same period, U.S. exports of commercial KI services more than doubled to reach $271 billion (Table 6-2; Appendix Table 6-19). This was spurred by growth in financial and business services (Appendix Table 6-23 and Appendix Table 6-24). The U.S. trade surplus widened in other business, finance, and communications services (Appendix Table 6-22) (for U.S. exports of R&D services, see sidebar, U.S. Trade in R&D Services).

Growth of China's exports resulted in its global share rising to 7% (Table 6-3; Figure 6-16). Similar to China, India's exports reached 7% of the global total. India became the world's second-largest exporter of computer and information services (26% global share), behind the EU (Appendix Table 6-21).

U.S. Trade in R&D Services

Trade in R&D services, part of U.S. trade in business services, occurs mostly within multinational companies (MNCs). In 2013, companies located in the United States exported $30 billion in these services and imported $32 billion, based on U.S. Bureau of Economic Analysis statistics (Appendix Table 6-25).

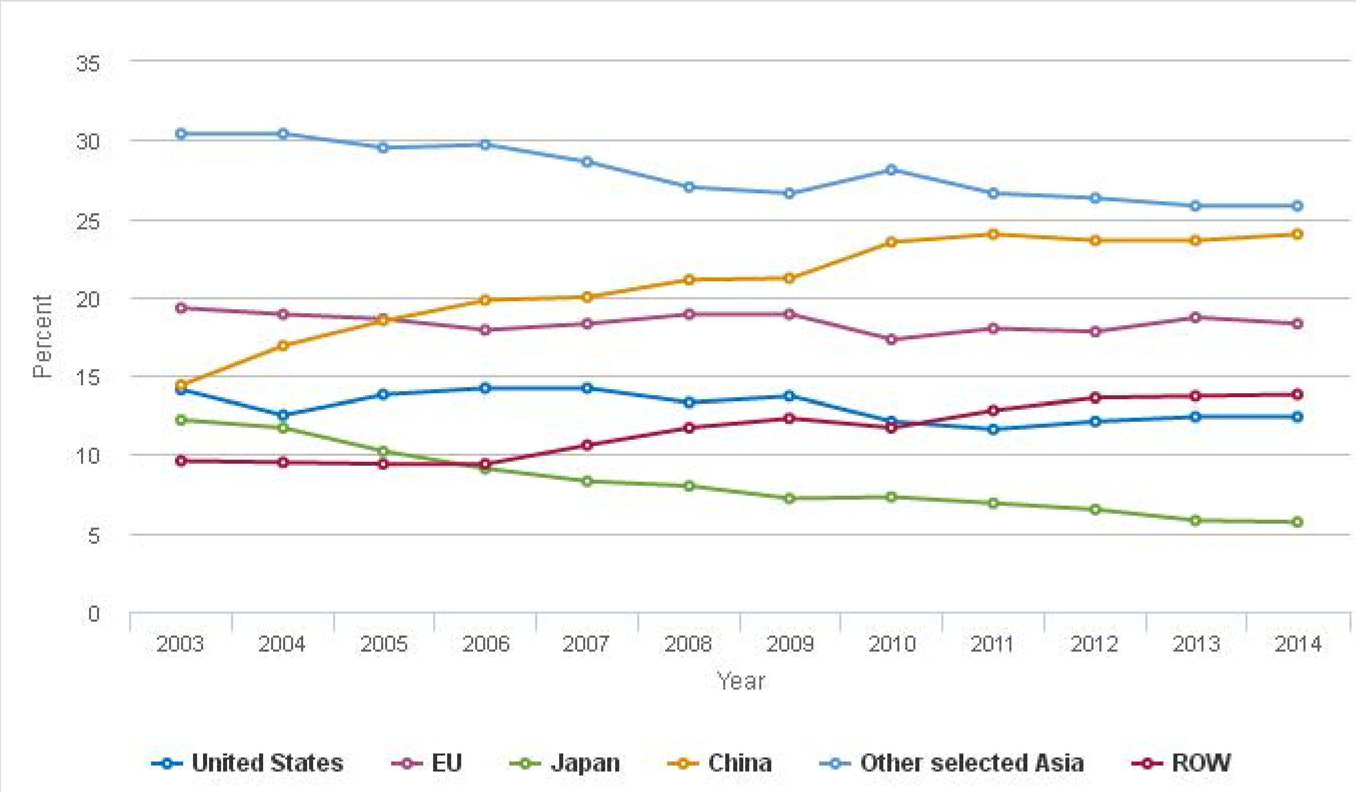
The European Union was the top destination for more than 40% of U.S. R&D services exports in 2013 and led U.S. imports (55%). Asia-Pacific was the second-largest destination for U.S. R&D services exports (16%) and provided 23% of U.S. imports. Among the Asian economies, Japan accounted for 10% of U.S. R&D services exports and 4% of U.S. imports. Although their shares of U.S. exports were negligible, China and India each provided 6% and 8%, respectively, of U.S. imports (see the "Cross-National Comparisons of R&D Performance" and "R&D by Multinational Enterprises" sections in chapter 4).

High-Technology Products

The global HT product export volume ($2.4 trillion in 2014) was dominated by ICT products—communications, computers, and semiconductors—with a collective value of $1.3 trillion, more than half of the total in this category. Aircraft and spacecraft; pharmaceuticals; and testing, measuring, and control instruments combined added about $1.1 trillion in 2014. HT product exports accounted for just 12% of the $20.0 trillion in total manufactured goods exports (Figure 6-17; Appendix Table 6-20 and Appendix Table 6-26, Appendix Table 6-27, Appendix Table 6-28, Appendix Table 6-29, Appendix Table 6-30, Appendix Table 6-31, Appendix Table 6-32, and Appendix Table 6-33).

Figure 6-17

Exports of HT products, by selected region/country/economy: 2003–14



EU = European Union; HT = high technology; ROW = rest of world.

NOTES: HT products include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Exports of the United States exclude exports to Canada and Mexico. Exports of the EU exclude intra-EU exports. Exports of China exclude exports between China and Hong Kong. Other selected Asia consists of Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand.

SOURCE: IHS Global Insight, World Trade Service database (2014). See appendix table 6-20.

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China is the world's largest exporter of HT goods and has a substantial surplus (Table 6-4; Figure 6-17 and Figure 6-18; Appendix Table 6-20). The EU and the United States are the second- and third-largest global exporters; they both have trade deficits. Taiwan, Japan, and South Korea are the next-largest exporters, each with a global share between 6% and 9%. For a list of regions and countries/economies in world trade data, see Appendix Table 6-34.

Table 6-4	**Exports and trade balance of HT products, by selected product and region /country/economy: 2014**

(Billions of dollars)

	ICT products		Pharmaceuticals		Testing, measuring, and control instruments		Aircraft and spacecraft	
Region/country /economy	Exports	Balance	Exports	Balance	Exports	Balance	Exports	Balance
United States	69.1	-108.3	47.7	-21.2	65.3	9.2	119.7	79.4
EU	82.4	-133.6	151.8	70.3	97.1	21.7	115.2	60.1
Japan	74.7	-8.1	5.3	-17.5	49.5	19.1	10.0	-2.0
China	497.5	201.2	14.9	0.3	69.1	-37.7	5.6	-34.5
Other selected Asia	501.3	245.0	18.5	1.3	98.3	39.4	10.7	-26.2

EU = European Union; HT = high technology; ICT = information and communications technology.

NOTES: HT products include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Exports of the United States exclude exports to Canada and Mexico. Exports of the EU exclude intra-EU exports. Exports of China exclude exports between China and Hong Kong. Other selected Asia consists of Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand.

SOURCE: IHS Global Insight, World Trade Service database (2014). See appendix table 6-20.

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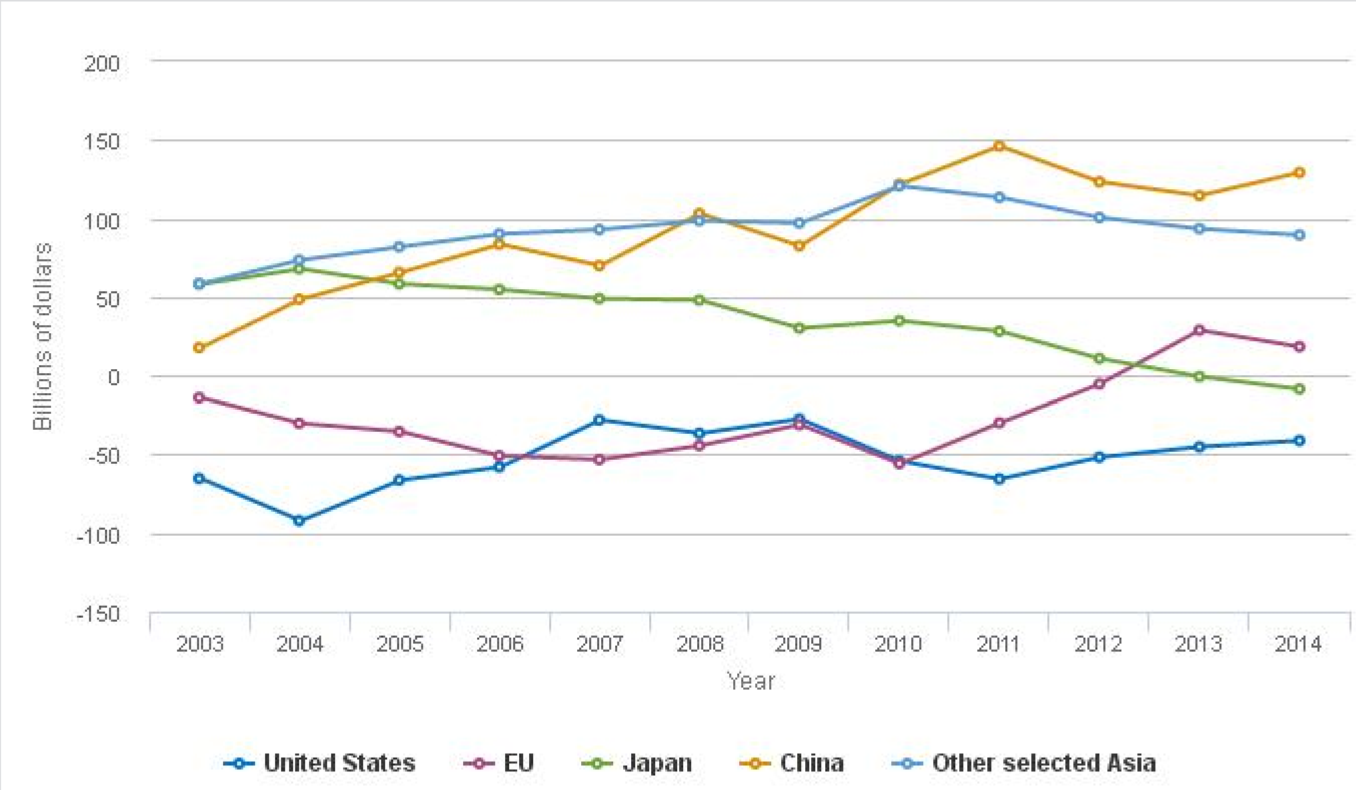
Figure 6-18

Trade balance of HT products, by selected region/country/economy: 2003–14



EU = European Union; HT = high technology.

NOTES: HT products include aerospace, communications and semiconductors, computers and office machinery, pharmaceuticals, and scientific instruments and measuring equipment. China includes Hong Kong. The EU excludes Cyprus, Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. Exports of the United States exclude exports to Canada and Mexico. Exports of the EU exclude intra-EU exports. Exports of China exclude exports between China and Hong Kong. Other selected Asia consists of Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand.

SOURCE: IHS Global Insight, World Trade Service database (2014). See appendix table 6-20.

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Trends of major exporters. China's HT products exports grew by more than threefold, pushing its global share from 14% in 2003 to 24% in 2014 (Figure 6-17; Appendix Table 6-20). However, because many of China's exports consist of inputs and components imported from other countries, China's exports and trade surplus are likely much less in value-added terms (see sidebar, International Initiative to Measure Trade in Value-Added Terms).

China's ICT exports, which dominate China's HT product exports, more than tripled to reach almost $500 billion over the last decade (Table 6-4; Appendix Table 6-27, Appendix Table 6-28, Appendix Table 6-29, and Appendix Table 6-30). China's ICT trade surplus expanded from almost $30 billion to more than $200 billion. Its exports of testing, measuring, and control instruments grew at the same pace to reach almost $70 billion (Appendix Table 6-31).

In the United States, HT product exports nearly doubled to reach $302 billion between 2003 and 2014 (Appendix Table 6-20). The U.S. global share slipped from 14% to 12%. The U.S. HT product trade deficit narrowed slightly (from $65 billion in 2003 to $41 billion in 2014) (Figure 6-18).[iii]

U.S. growth of HT product exports was led by pharmaceuticals and aircraft (Appendix Table 6-32 and Appendix Table 6-33). Exports of aircraft climbed to $120 billion, and the related trade surplus widened from $29 billion to $80 billion. Pharmaceutical exports nearly tripled in value to reach $48 billion. Growth of ICT product exports was stagnant between 2003 and 2014 as production of ICT goods migrated to China and other locations (Appendix Table 6-27, Appendix Table 6-28, Appendix Table 6-29, and Appendix Table 6-30). The U.S. trade deficit in ICT products widened from $79 billion to $108 billion (Table 6-4).

The EU's HT exports grew slightly faster than those of the United States over the last decade, and the EU's global share remained stable at 18%. Testing, measuring, and control instruments; pharmaceuticals; and aircraft drove the growth of the EU's HT exports (Table 6-4; Appendix Table 6-31, Appendix Table 6-32, and Appendix Table 6-33). The trade surpluses in these three products widened substantially. Exports of ICT products were flat, and the EU's trade deficit widened during this period (Appendix Table 6-27, Appendix Table 6-28, Appendix Table 6-29, and Appendix Table 6-30).

Japan's exports trailed the average for all developed countries, with its global share falling from 12% to 6%. Japan's decline from an export powerhouse in electronics reflects its lengthy economic stagnation, the financial difficulties of Japanese electronics firms, and Japanese companies moving their production to Taiwan, China, and other lower-cost locations.

Taiwan's HT exports more than doubled during this period, and it surpassed Japan in 2009 to become the largest developed Asian exporter of HT products. South Korea's HT exports nearly doubled, and it reached Japan's level in 2013. South Korea and Taiwan's rapid gains in HT exports were due to growth of ICT product exports (Appendix Table 6-27, Appendix Table 6-28, Appendix Table 6-29, and Appendix Table 6-30).

Vietnam grew the fastest of any developing country, with its HT exports increasing from less than $1 billion to $39 billion. Vietnam has become a low-cost location for assembly of cell phones and other ICT products, with some firms shifting production out of China, where labor costs are higher. India's exports rose sevenfold to reach $28 billion because of expansion in pharmaceuticals and ICT products.

[iii] The U.S. trade balance is affected by many factors, including currency fluctuations, differing fiscal and monetary policies, and export subsidies and trade restrictions between the United States and its trading partners.

International Initiative to Measure Trade in Value-Added Terms

Manufactured goods increasingly embody elements produced by global supply chains, and the conventional trade measures used here count the gross value of both intermediate and final goods upon crossing international borders. The Trade in Value Added joint initiative of the Organisation for Economic Co-operation and Development (OECD) and the World Trade Organization (WTO) aims to correct this shortcoming by recording only net value added at each crossing. This approach has two advantages: First, it provides more accurate measures of global trade volumes; and second, it makes possible better estimates of national contributions to the value of goods and services in international trade.

The iPhone offers a simple example. The conventional measures show a large trade deficit with China, the point of final assembly. The OECD's estimate, net of value added by supplier economies, shows a much smaller estimated trade deficit with China and larger trade deficits with countries that supply inputs to the iPhone (Table 6-D).

OECD/WTO estimates of trade in value-added terms are derived from OECD country-level input-output tables. Input-output tables track the interrelationships among domestic industries and between domestic industries and consumers—households, government, industry, and export customers.

The most recent version of the OECD/WTO database, released in October 2015, covers 61 economies (including all OECD countries, Brazil, China, India, Indonesia, Russia, and South Africa) and the years 1995, 2000, 2005, and 2008–2011. Trade in value-added indicators and additional information are available at http://www.oecd.org/industry/ind/measuringtradeinvalue-addedanoecd-wtojointinitiative.htm.

Table 6-D **U.S. trade balance in iPhones, by selected country/economy**

(Millions of dollars)

Type of trade	China	Germany	South Korea	Taiwan	ROW
Balance (gross)	-1,646	0	0	0	0
Balance (value added)	-65	-161	-800	-207	-413

ROW = rest of world.

SOURCE: Organisation for Economic Co-operation and Development, Trade in Value-Added: Concepts, Methodologies and Challenges, http://www.oecd.org/sti/ind/49894138.pdf, accessed 15 March 2013.

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Multinational Companies in U.S. Knowledge- and Technology-Intensive Industries

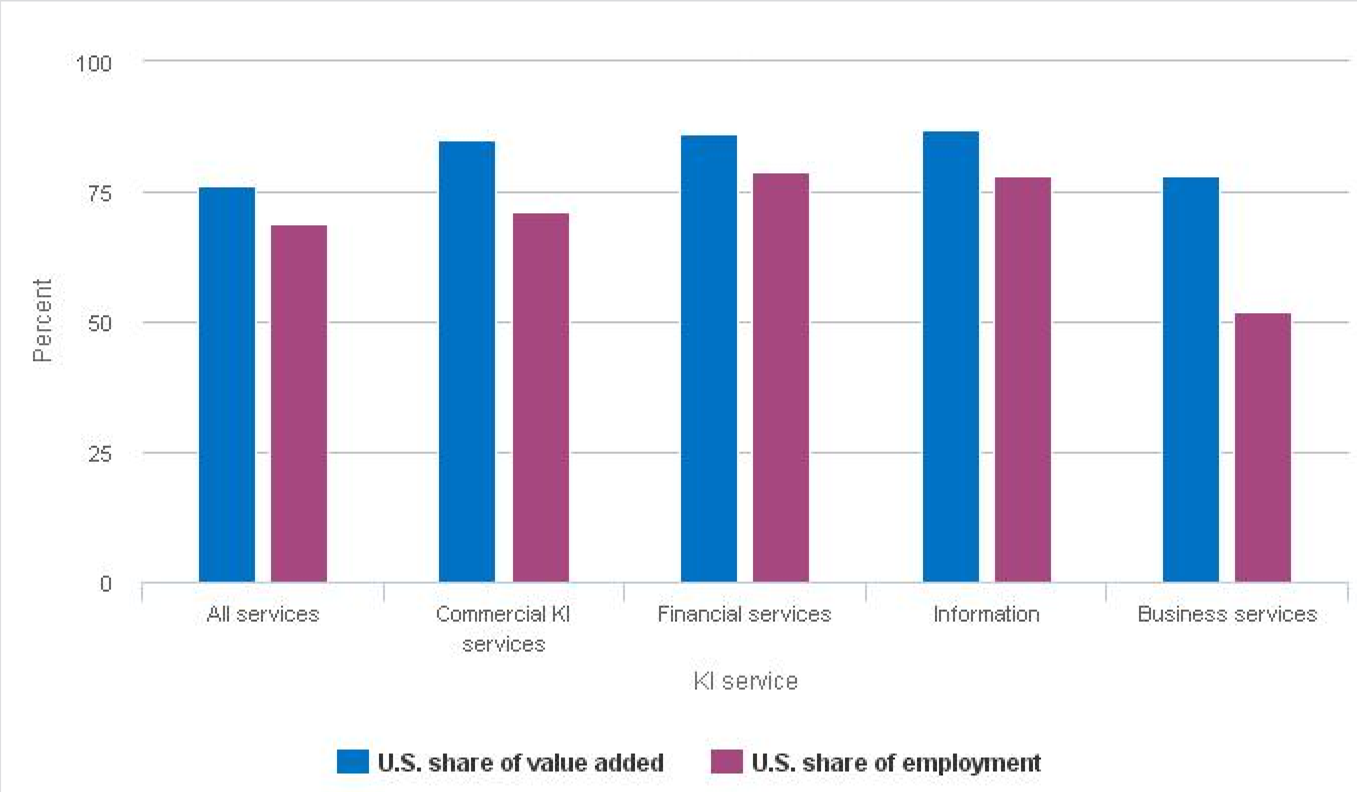
U.S. Bureau of Economic Analysis (BEA) data on multinational companies in KTI industries are not directly comparable with the world industry data used in the previous sections. However, BEA data provide additional information on the globalization of activity and employment and direct investment of MNCs operating in the United States and the activities of U.S. MNCs outside of the United States in these industries.

Commercial Knowledge-Intensive Services Industries

U.S. multinationals in commercial KI services industries—financial, business, and information services—generated $1.3 trillion in value added and employed 7.9 million workers worldwide in 2013 (Appendix Table 6-35). Production and employment are concentrated in the United States. The U.S. share of worldwide value added was highest in information services and financial services (86%–87% each) and accounted for 78% of business and financial services in 2013 (Figure 6-19; Appendix Table 6-35). Information and financial services also had the highest shares of U.S. employment (78%–79%). Business services had a considerably lower share (52%).

Figure 6-19

Globalization indicators of U.S. multinationals in commercial KI services: 2013



KI = knowledge intensive.

NOTES: Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs. Commercial KI services are classified by the Organisation for Economic Co-operation and Development and include business, financial, and information. Internet and data processing are part of communications. Management, scientific, and technical and computer system design are part of business services.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. Direct Investment Abroad: Activities of U.S. Multinational Enterprises, Financial and Operating Data for U.S. Multinational Companies (2009–13), http://www.bea.gov /international/di1usdop.htm, accessed 15 February 2015. See appendix table 6-35.

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High-Technology Manufacturing Industries

U.S. multinationals in the HT manufacturing industries (excluding aircraft and spacecraft) generated nearly $500 billion and employed 2.2 million workers worldwide in 2013 (Figure 6-20; Appendix Table 6-35).[i] Production and employment of HT manufacturing industries is less concentrated in the United States than commercial KI services, especially in employment (Appendix Table 6-35). The U.S. share of value-added output is highest in semiconductors (84%), followed by pharmaceuticals (82%). The U.S. share of employment is less than half in navigational, measuring, and other instruments, and accounts for half of the communications workforce.

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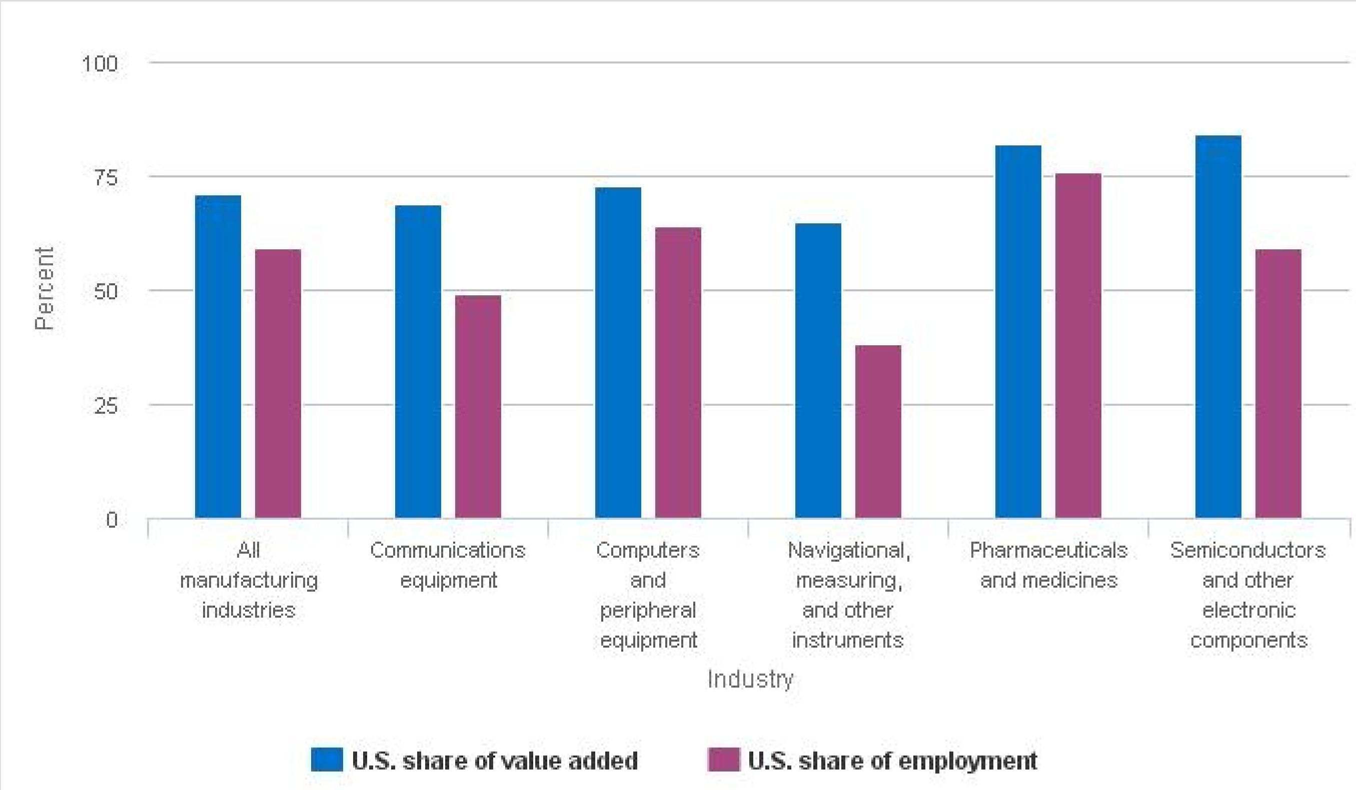
[i] Bureau of Economic Analysis data on inward and outward direct investment in aircraft and spacecraft are not available.

Figure 6-20

Globalization indicators of U.S. multinationals in selected manufacturing industries: 2013



NOTE: Value added is the amount contributed by a country, firm, or other entity to the value of a good or service and excludes purchases of domestic and imported materials and inputs.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. Direct Investment Abroad: Activities of U.S. Multinational Enterprises, Financial and Operating Data for U.S. Multinational Companies (2009–13), http://www.bea.gov/international/di1usdop.htm, accessed 15 February 2015. See appendix table 6-35.

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U.S. Direct Investment Abroad

The stock of U.S. direct investment abroad in computer and electronic products, which includes the HT industries of communications; semiconductors; and testing, measuring, and control instruments, was $97 billion in 2013 (Table 6-5), with just over half going to the Asia and Pacific region.[ii] Singapore was the largest recipient in this region (19%), followed by China (8%) and Japan (6%). The EU received about a third.

[ii] The Asia and Pacific region includes Australia, China, Hong Kong, India, Indonesia, Japan, Malaysia, New Zealand, the Philippines, Singapore, South Korea, Taiwan, and Thailand.

Table 6-5	U.S. outward foreign direct investment in selected industries and regions/countries: 2013

(Percent)

Region/country	Computers and electronic products	Information	Finance	Professional, scientific, and technical services
All countries total ($billions)	96.9	157.5	767.2	98.8
Selected regions/countries (share of total)				
EU	31.9	55.1	41.9	52.3
Asia and Pacific	51.5	21.3	16.9	28.7
China	8.1	5.7	1.4	3.2
India	0.4	-1.0	0.4	11.2
Japan	5.8	4.0	9.4	2.1
Singapore	19.4	3.3	2.1	0.9
South Korea	3.2	0.1	0.7	0.6
All others	14.6	9.2	2.9	10.7

EU = European Union.

NOTES: Data are preliminary. Outward foreign investment is on a historical cost-position basis. Finance excludes depository institutions. All others includes Australia, Indonesia, Malaysia, New Zealand, Philippines, Taiwan, and Thailand. China includes Hong Kong.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, U.S. Direct Investment Abroad: Activities of U.S. Multinational Enterprises, Financial and Operating Data for U.S. Multinational Companies (2009–13), http://www.bea.gov/international/di1usdop.htm, accessed 15 February 2015.

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The stock of U.S. direct investment abroad in information; finance; and professional, scientific, and technical services, which comprise commercial KI services industries, was $1.0 trillion in 2013 (Table 6-5). Financial services accounted for most U.S. direct investment abroad, with far smaller stocks for information and professional, scientific, and technical services. The EU is the largest recipient in these three industries, with shares ranging from 42% to 55%. The Asia and Pacific region, including Japan, is the next largest, with shares of 17%–29% in these industries. India received a sizable amount of U.S. foreign direct investment (FDI) in professional, scientific, and technical services.

Foreign Direct Investment in the United States

The stock of inward FDI in U.S. computer electronics manufacturing industries was $49 billion in 2013, less than the amount the United States invested abroad in these industries (Table 6-5 and Table 6-6). Limited data on the geographic region show that the Asia and Pacific region is a major investor, with a share of 37%. Japan has a share of 20% in FDI in this industry.

Table 6-6 **Foreign direct investment in selected U.S. industries, by selected region/country: 2013**

(Percent)

Region/country	Computers and electronic products	Information	Finance	Professional, scientific, and technical services
All countries total ($billions)	49.4	148.6	364.7	104.2

Region/country	Computers and electronic products	Information	Finance	Professional, scientific, and technical services
Selected regions/countries (share of total)				
EU	na	na	63.0	80.0
Asia and Pacific	37.0	18.0	11.0	na
China	0.0	na	na	na
India	0.0	0.0	na	3.0
Japan	20.0	na	9.0	7.0
Singapore	na	0.0	na	0.3
South Korea	0.1	0.0	0.1	0.0
All others	na	na	na	na

NOTES: na = not applicable.

EU = European Union.

Data are preliminary. Foreign direct investment is on a historical cost-position basis. Finance excludes depository institutions. All others includes Australia, Indonesia, Malaysia, New Zealand, Philippines, Taiwan, and Thailand.

SOURCE: Bureau of Economic Analysis, International Economic Accounts, Foreign Direct Investment in the U.S.: Balance of Payments and Direct Investment Position Data, http://www.bea.gov/international/di1fdibal.htm, accessed 15 February 2015.

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Similarly, the stock of inward FDI in U.S. commercial KI services, at $618 billion in 2013, was less than the amount the United States invested abroad in these industries (Table 6-5 and Table 6-6). The EU is the largest investor in finance and professional, scientific, and technical services. The Asia and Pacific region accounts for 18% of investment in information services.

Innovation-Related Indicators of the United States and Other Major Economies

The fourth section of this chapter examines several innovation-related measures in industry, with a focus on KTI industries. The OECD defines innovation as the "implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method" (OECD/Eurostat 2005:46–47). Innovation is widely recognized as instrumental to realizing commercial value in the marketplace and as a driver of economic growth. New ICT, for example, has stimulated the creation of new products, services, and industries that have transformed the world economy over the past several decades.

This section will present data on how innovation activity varies among U.S. industries, using information from NSF's Business R&D and Innovation Survey (BRDIS) (see sidebar, Data Sources).[i] The section also includes three indicators of activities that can facilitate innovation but do not themselves constitute innovation. Two of these, patents and trade in royalties and fees, are indicators of invention—they protect intellectual property in inventions that can have value for commercial innovations. The third indicator concerns venture capital financing for U.S. HT small businesses, which can help bring new products and services to market.

[i] The NSF BRDIS definition of innovation is very similar to the OECD definition.

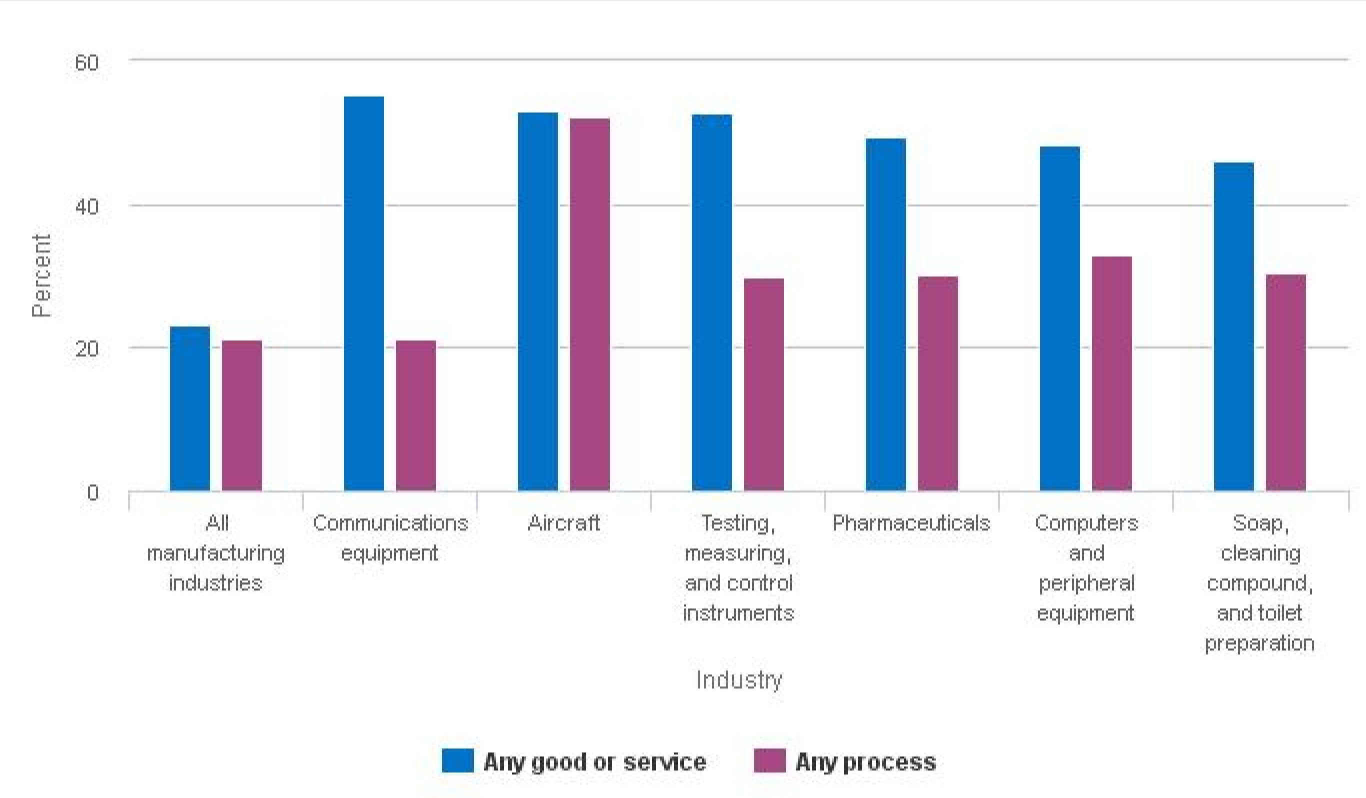
Innovation Activities by U.S. Businesses

U.S. KTI industries have a much higher incidence of innovation—introducing new products, services, or processes—than other industries.

The five U.S. HT manufacturing industries—aircraft; communications and semiconductors; computers; pharmaceuticals; and testing, measuring, and control instruments—reported rates of product innovation that were at least double the manufacturing sector average (Figure 6-21). Most of these industries reported significantly higher rates of innovation in both goods and services, suggesting that high rates of innovation by manufacturing companies go hand-in-hand with innovations in services. Most of these industries also reported higher-than-average rates of process innovations, particularly in production methods, logistics, and delivery methods.

Figure 6-21

Share of U.S. manufacturing companies reporting innovation activities, by selected industry: 2008–10



NOTES: The survey asked companies to identify innovations introduced from 2008 to 2010. Data may not be internationally comparable.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (2010).

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Innovation is also higher in several commercial KI services industries in comparison with other nonmanufacturing industries (Figure 6-22).[i] Software firms lead in incidence of innovation, with 69% of companies reporting the introduction of a new product or service, compared with the 9% average for all nonmanufacturing industries. Innovation is also three to four times higher than the nonmanufacturing average in three other industries—computer systems design, data processing and hosting, and scientific R&D services.

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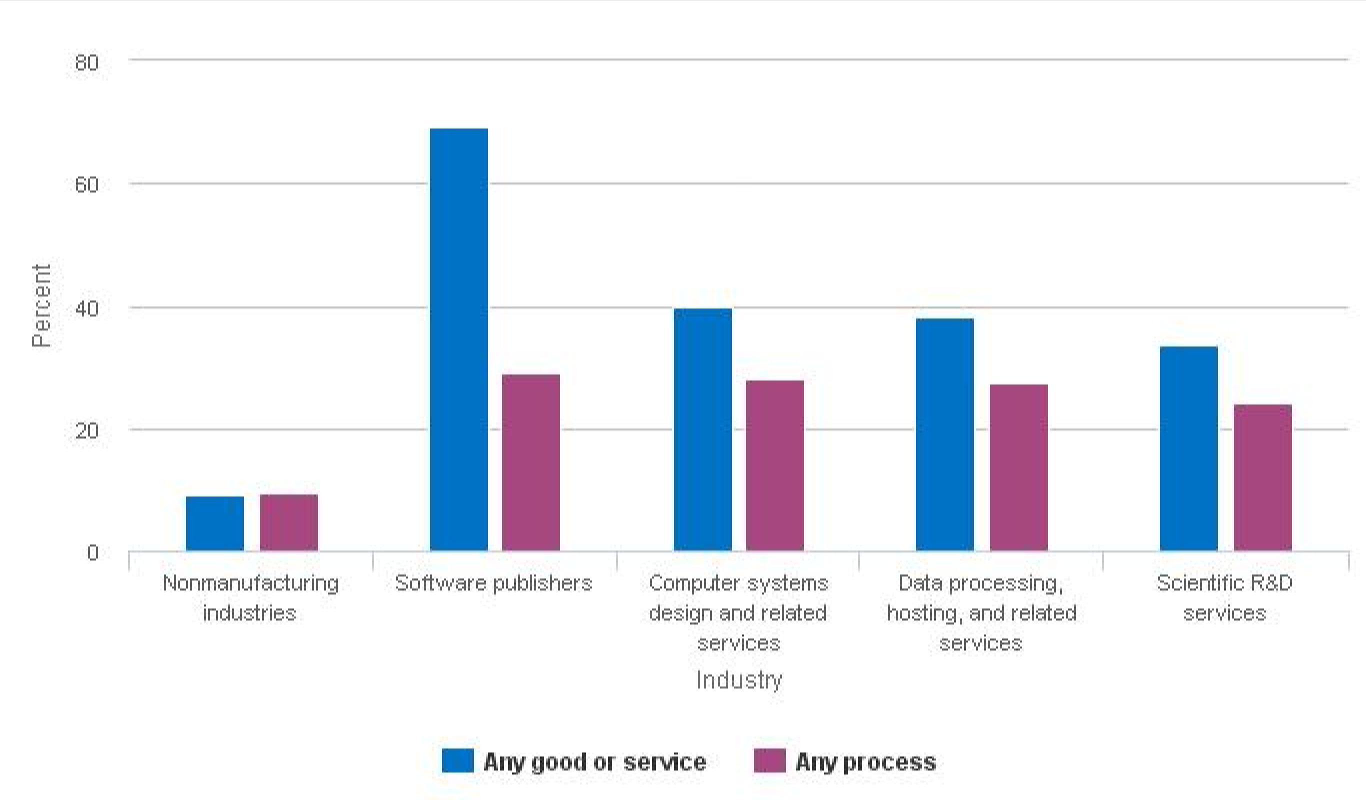
[i] BRDIS data are not available for the entire U.S. service sector.

Figure 6-22

Share of U.S. nonmanufacturing companies reporting innovation activities, by selected industry: 2008–10



NOTES: The survey asked companies to identify innovations introduced from 2008 to 2010. The sum of yes plus no percentages may not add to 100% because of item nonresponse to some innovation question items. Figures are preliminary and may later be revised. Data may not be internationally comparable.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (2010).

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Global Trends in Patenting

Nations assign patents to inventors to exclude others from making, using, or selling the invention for a limited period in exchange for publicly disclosing details and licensing the use of the invention.

Patents are a rough and incomplete indicator of innovation. Although patents of commercialized inventions provide important information on innovation, most patented inventions are never commercialized. Conversely, many products, services, and processes that are commercialized are not patented. Companies may choose different means to protect their intellectual property and innovation activities; for example, using trade secrets or copyrights (Figure 6-23). In addition, technical standards are considered important for innovation and may have greater impact on economic growth than patents (see sidebar, Technical Standards, Innovation, and Economic Growth).

Technical Standards, Innovation, and Economic Growth

A technical standard is "a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose."* Standards are widely used in industries and firms that produce, use, or rely on information and communications technologies.

One example of a technical standard is Apple's operating system for the iPhone, which governs the interface and function of the large number of iPhone applications (apps). Apple's technical standards allow a large number of companies and developers to provide apps that increase the utility, value, and desirability of the iPhone.

The number of standards is proliferating in the global economy, coinciding with the globalization of HT value chains and the complexity and persuasiveness of technologies embedded in products and services. For example, the semiconductor industry is estimated to have at least 1,000 standards.

Standards increase industry growth and productivity, which can increase a country's economic growth. The wide-ranging impacts of standards include the following (Tassey 2015:189–90):

- Raising the efficiency of R&D
- Expanding existing markets and creating new markets for an industry's products and services
- Increasing the growth and productivity of incumbent firms
- Facilitating the entry of small and medium-sized firms, which can increase innovation and growth of the entire industry

Standards consist of two types: product and nonproduct. Product standards govern the performance and function of components used in HT products and prescribe procedures to test product development, production, and market transactions. In the United States, businesses have typically developed product standards by reaching voluntary consensus with relevant stakeholders, including firms in the industry, suppliers, and R&D laboratories.

Nonproduct standards have more general and broader functions than product standards. These standards generally govern the efficiency, operation, and performance of the entire industry. Examples include measurement and test methods, interface standards, scientific and engineering databases, and standard reference materials (Tassey 2015:192). Nonproduct standards have become increasingly important because many HT products are a complex mix of goods and services.

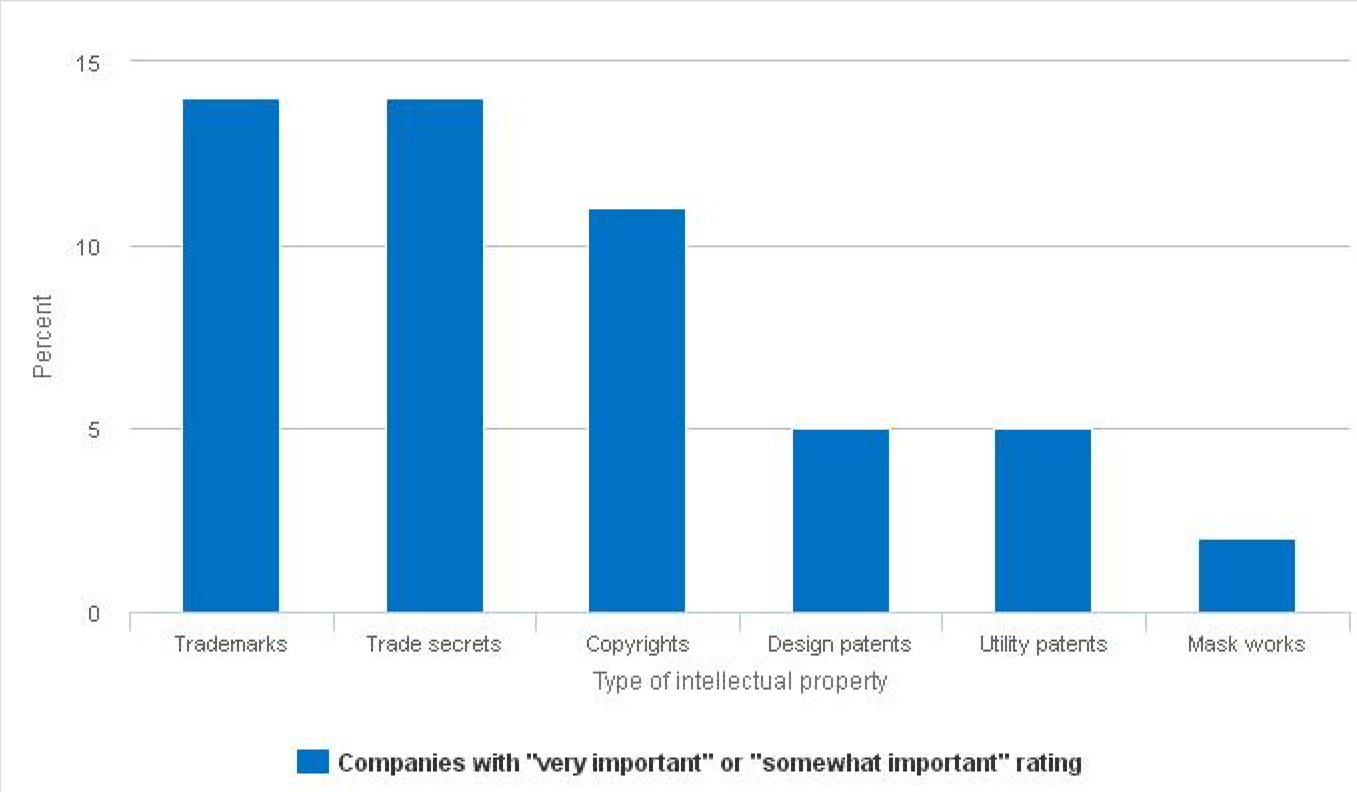
The two types of nonproduct standards are technical and basic. Technical nonproduct standards are operational, applied functions and guidelines that govern the performance, function, and interaction of services and products. U.S. industries have also developed technical nonproduct standards through a voluntary consensus approach. The second type is basic nonproduct standards that include generic measurement and test methods that are typically derived from fundamental scientific principles, such as laws of physics. Although these standards have wide applications in industry, firms and even industries tend to underinvest because they are expensive and require an extensive and specialized scientific infrastructure. Therefore, basic standards are considered a public good and usually have some degree of public involvement in many developed countries. The National Institute of Standards and Technology provides this function for the United States.

Researchers and policymakers are increasingly interested in standards because they appear to play an important role in facilitating technological development, innovation, and increasing economic growth. Several studies have found that standards are significantly associated with economic growth through greater diffusion of knowledge. However, the impact of standards on innovation and economic growth is not fully understood because of their complexity and the limited amount of research in this area. Furthermore, the existing research has mostly focused on developed countries with few studies on China and other developing countries (Ernst 2013:5).

* The source of this definition is the International Organization for Standardization (http://www.iso.org/iso/home/standards.htm).

Figure 6-23

Companies rating intellectual property as being very or somewhat important: 2011



SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (2011).

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Patents may provide important information for subsequent inventions and technological advances. However, patents may be obtained to block rivals and negotiate with competitors, to use in lawsuits, or to build “thickets” of patents to impede or raise others’ cost of R&D and innovation (Noel and Schankerman 2009:2). Research suggests that some organizations and countries pursue “strategic patenting” to block competitors and to monetize patents through licensing and other activities (Ernst 2013:1–9). The globalization of production has coincided with a rise in patent protection across multiple countries that is sometimes used as a tool for corporate transfer pricing and tax planning.

This discussion focuses largely on patent activity at the U.S. Patent and Trademark Office (USPTO). It is one of the largest patent offices in the world and has a significant share of applications and grants from foreign inventors because of the size and openness of the U.S. market.[i] Although U.S. patents are naturally skewed toward U.S. inventions, these market attributes make U.S. patent data useful for identifying trends in global inventiveness.

This section also deals with patents filed in the world’s three largest patenting centers: the United States, the EU, and Japan. Because of the high costs associated with patent filing and maintenance in these three patent offices, inventions covered by these patents are likely to be valuable.

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[i] The Japan Patent Office is also a major patent office but has a much smaller share of foreign patents than the USPTO and the European Patent Office.

U.S. Patent and Trademark Office Grants

The USPTO granted almost 300,000 patents worldwide in 2014 (Appendix Table 6-36 and Appendix Table 6-37). The United States received nearly half (48%) of them (Figure 6-24). Japan, the next largest, accounted for 18%, followed by the EU (15%).

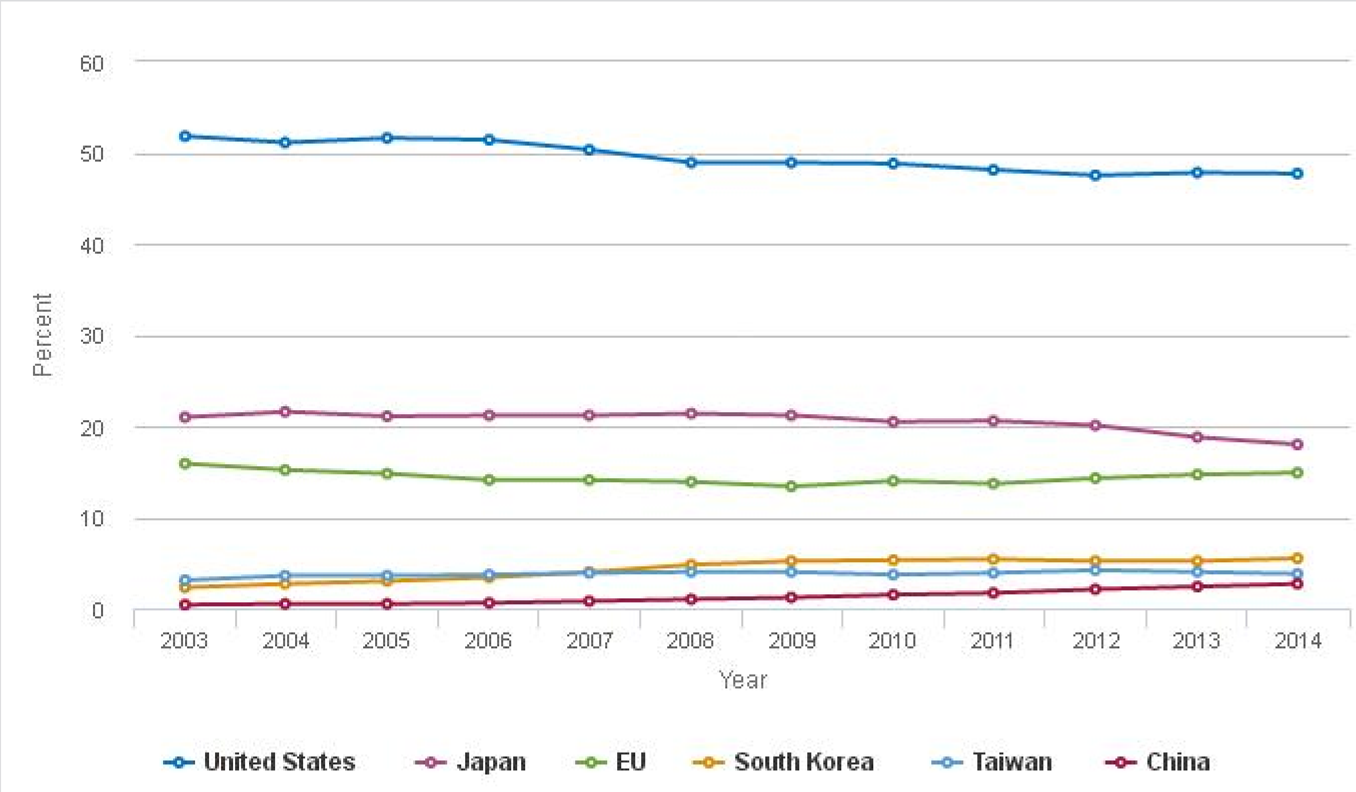
After flat growth earlier in the decade, the number of USPTO patents nearly doubled between 2008 and 2014 (Appendix Table 6-37). The rapid growth likely reflects the globalization of KTI and other industries that are patent intensive, particularly in developed and developing Asian economies. In addition, growth may be due to the recovery from the global recession, along with USPTO efforts to decrease its backlog of patent applications.[ii]

Faster growth of patents granted to non-U.S. inventors reduced the U.S. share from 52% in 2003 to 48% in 2014 (Figure 6-24). The decline in the U.S. share likely indicates increased technological capabilities abroad, globalization that makes patent protection in foreign countries more important, and patenting by U.S.-based inventors located abroad, such as patents granted to inventors located in subsidiaries of U.S. MNCs.

[ii] The United States enacted the Leahy–Smith America Invents Act in 2011, a comprehensive reform of U.S. patent law. The Act included a new fast track option by the USPTO to review patent applications from start-up companies and the provision of additional resources to the USPTO to reduce its backlog of patent applications. For more information, see https://www.whitehouse.gov/the-press-office/2011/09/16 /president-obama-signs-america-invents-act-overhauling-patent-system-stim.

Figure 6-24

USPTO patents granted, by selected region/country/economy of inventor: 2003–14



EU = European Union; USPTO = U.S. Patent and Trademark Office.

NOTES: China includes Hong Kong. Patent grants are fractionally allocated among regions/countries/economies based on the proportion of the residences of all named inventors.

SOURCES: Science-Metrix, LexisNexis, and SRI International. See appendix table 6-37.

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Japan's share fell slightly, and the EU's share remained steady between 2008 and 2014 (Figure 6-24). USPTO patenting by Japan and the EU may indicate economic factors or an increased preference to patent in their home patent offices.

Patenting activity in the Asian economies of South Korea, Taiwan, China, and India increased strongly over the last decade. South Korea's share more than doubled to reach 5.5% (Figure 6-24). Taiwan's share increased to 3.8%. China grew the fastest of any economy, although from a low base, resulting in its share rising from 0.4% to 2.7%. India also grew from a low base with its share reaching 1.0% (Appendix Table 6-37).

U.S. Patent and Trademark Office Patenting Activity by U.S. Companies

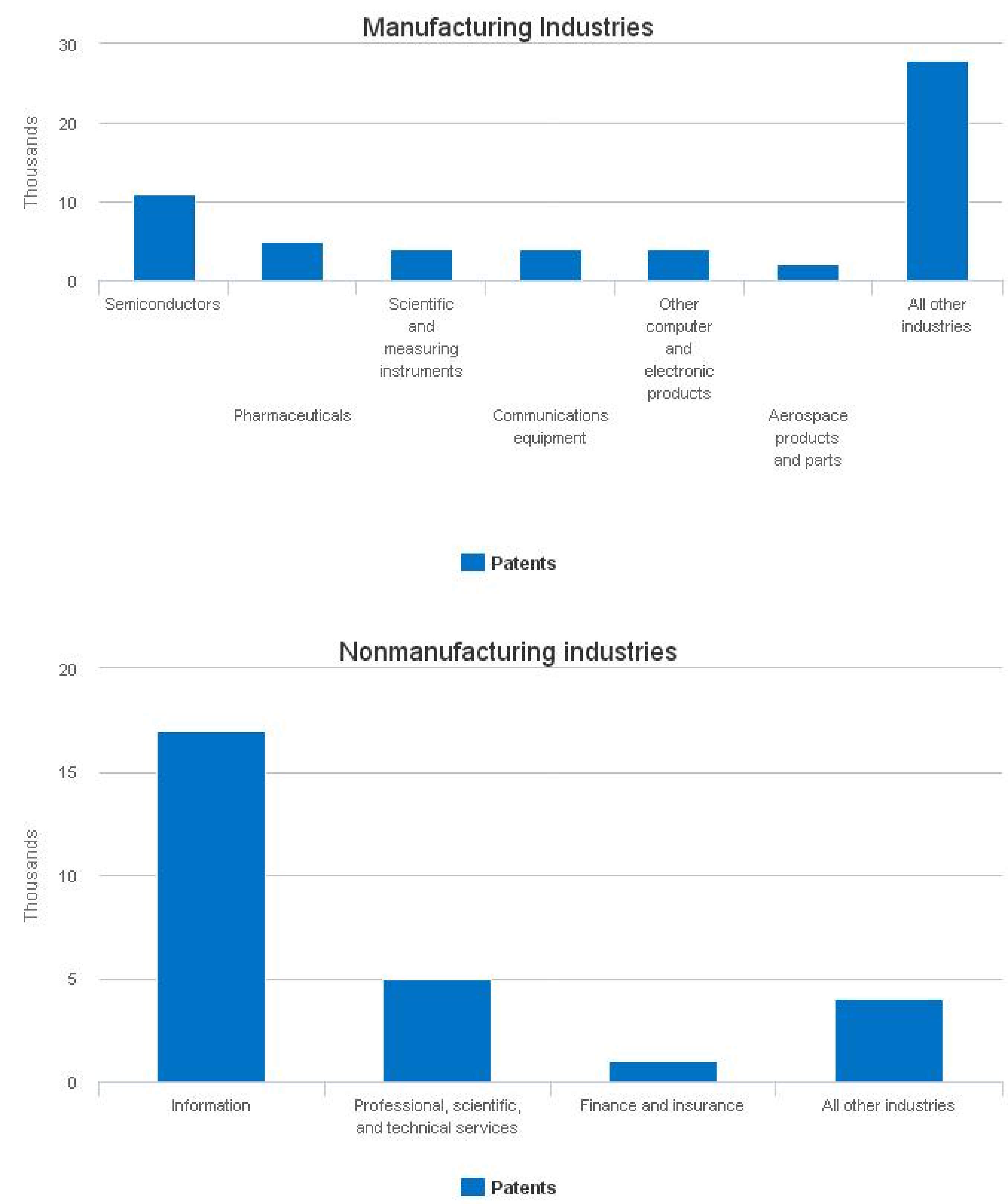
U.S. KTI industries are far more active in patenting than other industries because patenting is relatively more important for their intellectual property protection than that of non-KTI industries (Figure 6-25). (The BRDIS data on USPTO patents are not comparable with the USPTO patent data presented in the previous and following sections. [iii]) U.S. HT industries received about half of the 58,000 patents granted to all U.S. manufacturing industries in

2012 (Figure 6-25), compared with its one-fourth share of value added of all manufacturing industries. The U.S. semiconductor industry was issued the largest number of patents (11,000) among these HT industries, followed by 2,000–5,000 each for the other four.

[iii] The BRDIS data are collected from a sample of U.S. firms, whereas the USPTO data are from administrative records of all U.S. inventors, including individuals and nonprofits.

Figure 6-25

USPTO patents granted, by selected U.S. industry: 2012



USPTO = U.S. Patent and Trademark Office.

NOTES: Detail may not add to total because of rounding. Industry classification is based on the dominant business code for domestic R&D performance, where available. For companies that did not report business codes, the classification used for sampling was assigned. Statistics are based on companies in the United States that reported to the survey, regardless of whether they did or did not perform or fund R&D. These statistics do not include an adjustment to the weight to account for unit nonresponse. For a small number of companies that were issued more than 100 patents by USPTO, counts from USPTO.gov were used to supplement survey data.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (2012).

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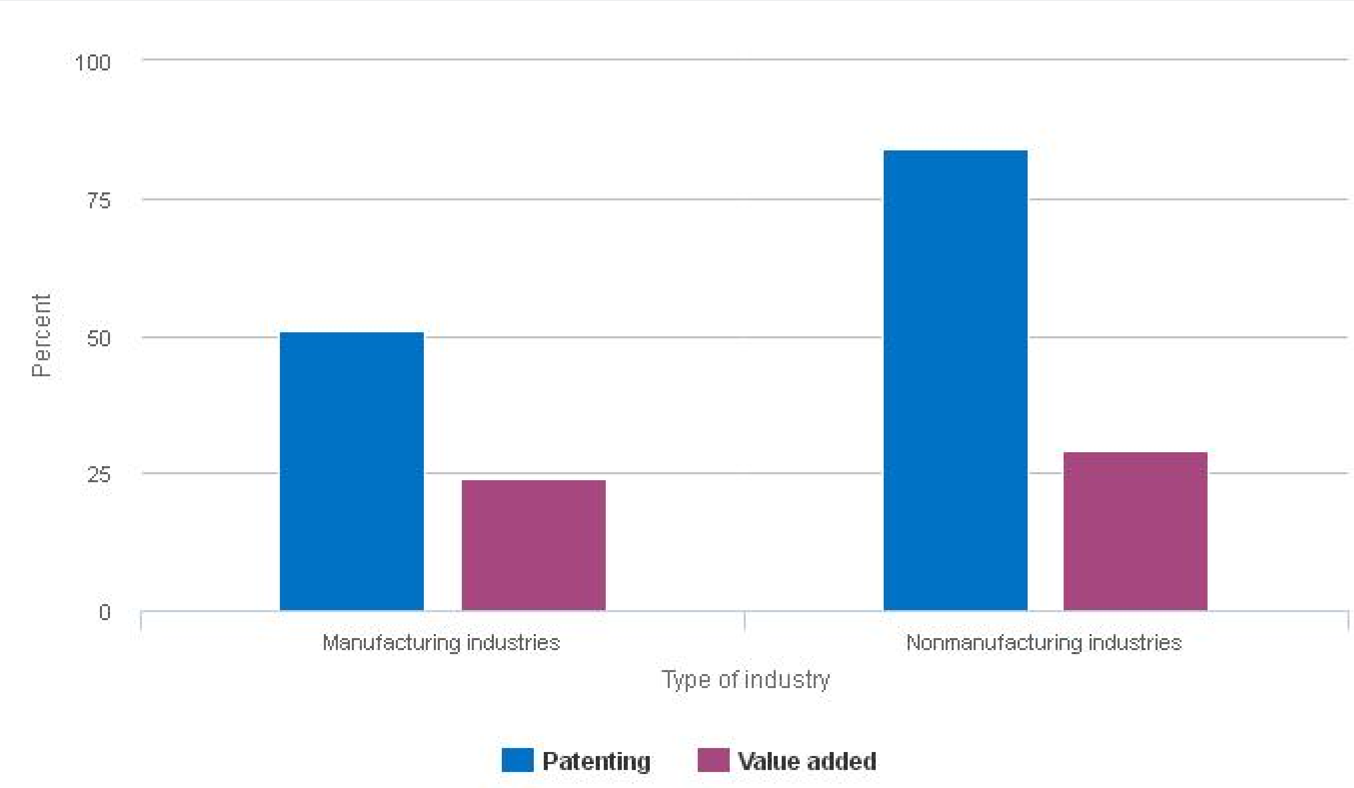
U.S. commercial KI services received 84% of the 27,000 patents issued to nonmanufacturing industries in 2012 (Figure 6-26). These industries' share of patents is much higher than their value-added share of all nonmanufacturing industries (29%), similar to the position of HT manufacturing industries. The information services industry accounted for 17,000 patents, three-fourths of the patents issued to commercial KI services; professional, scientific, and technical services were ranked second with 5,000 patents.

Figure 6-26

Selected industry category share of value-added and USPTO patents granted, by manufacturing and nonmanufacturing industries: 2012



USPTO = U.S. Patent and Trademark Office.

NOTES: Detail may not add to total because of rounding. Industry classification is based on the dominant business code for domestic R&D performance, where available. For companies that did not report business codes, the classification used for sampling was assigned. Statistics are based on companies in the United States that reported to the survey, regardless of whether they did or did not perform or fund R&D. These statistics do not include an adjustment to the weight to account for unit nonresponse. For a small number of companies that were issued more than 100 patents by USPTO, counts from USPTO.gov were used to supplement survey data.

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Business R&D and Innovation Survey (2012).

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U.S. Patent and Trademark Office Patents Granted, by Technology Area

This section discusses patterns and trends of technologies that are closely linked to science or KTI industries. The ICT category consists of six technologies—basic communication processes, computer technology, digital communications, IT methods for management, semiconductors, and telecommunications. The instruments category consists of five technologies—analysis of biological materials, control, measurement, medical technology, and optics. The three remaining technologies are microstructural and nanotechnology, biotechnology, and pharmaceuticals. The classification used in this section was developed by the World Intellectual Property Organization and is therefore not compatible with the NSF technology classification used in previous editions (see sidebar, New Technology Classification of U.S. Patent and Trademark Office Patents).

ICT accounted for 38% of all USPTO patents in 2014 led by computer technology (17%), followed by semiconductors, telecommunications, and digital communications, each with shares of 5%–6% (Figure 6-27; Appendix Table 6-38, Appendix Table 6-39, Appendix Table 6-40, Appendix Table 6-41, Appendix Table 6-42, and Appendix Table 6-43). The ICT share grew from 26% to 38% since 2003, consistent with the growing use of ICT by a wide variety of industries. The propensity to patent ICT may also have increased. Computer technology led the growth of ICT patents with its share climbing from 9% to 17%.

New Technology Classification of U.S. Patent and Trademark Office Patents

Science and Engineering Indicators 2016 uses a slightly different technology classification of patents compared with *SEI 2012* and *SEI 2014*. The classification system used in *SEI 2016* was developed by the World Intellectual Property Organization (WIPO) (Schmoch 2008:1–15). The WIPO classification has several desirable features for international comparability of patenting activity in technologies:

- The WIPO classification is designed for country comparison and covers 35 technology fields, including HT and science-based technologies (e.g., information and communications technologies [ICT], biotechnology, pharmaceuticals) (Table 6-E).
- The WIPO classification of patents is based on International Patent Classification (IPC) codes, which are used by all major patent offices. The use of IPC codes permits international comparison of patent offices.
- WIPO has updated the classification over time to reflect changes in patent activity and technologies, including adding more ICT fields.

Table 6-E WIPO patent classification of technologies

WIPO patent classification of technologies	
Analysis of biological materials	Macromolecular chemistry and polymers
Audiovisual technology	Materials and metallurgy
Basic communication processes	Measurement
Basic materials chemistry	Mechanical elements
Biotechnology	Medical technology
Chemical engineering	Microstructural and nanotechnology
Civil engineering	Optics
Computer technology	Organic fine chemistry
Control	Other consumer goods

WIPO patent classification of technologies	
Digital communication	Other special machines
Electrical machinery, apparatus, and energy	Pharmaceuticals
Engines, pumps, and turbines	Semiconductors
Environmental technology	Surface technology and coating
Food chemistry	Telecommunications
Furniture and games	Textile and paper machines
Handling	Thermal processes and apparatus
IT methods for management	Transport
Machine tools	

IT = information technology; WIPO = World Intellectual Property Organization.

SOURCE: Schmoch U. 2008. Concept of a technology classification for country comparisons: Final report to the World Intellectual Property Organization. Karlsruhe, Germany: Fraunhofer Institute for Systems and Innovation Research, http://www.wipo.int/export/sites/www/ipstats/en/statistics/patents/pdf/wipo_ipc_technology.pdf, accessed 5 September 2015.

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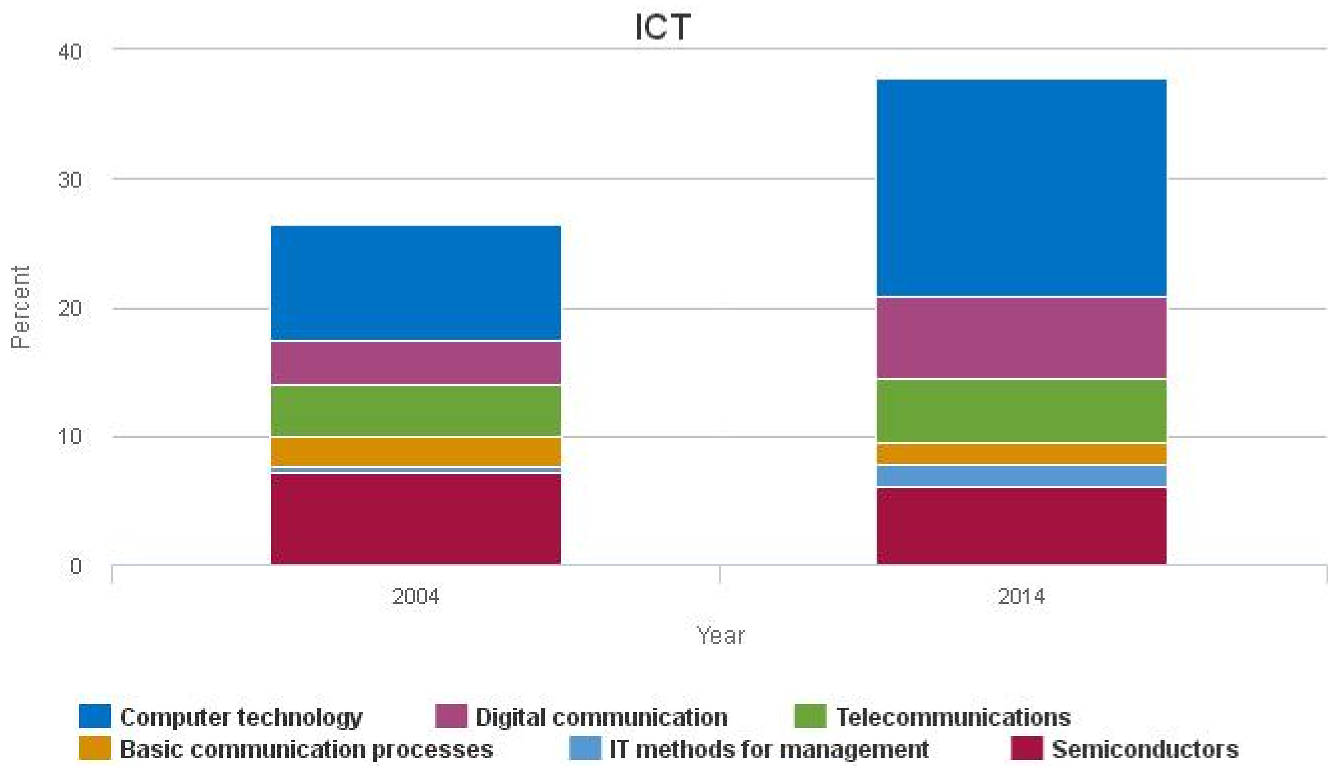
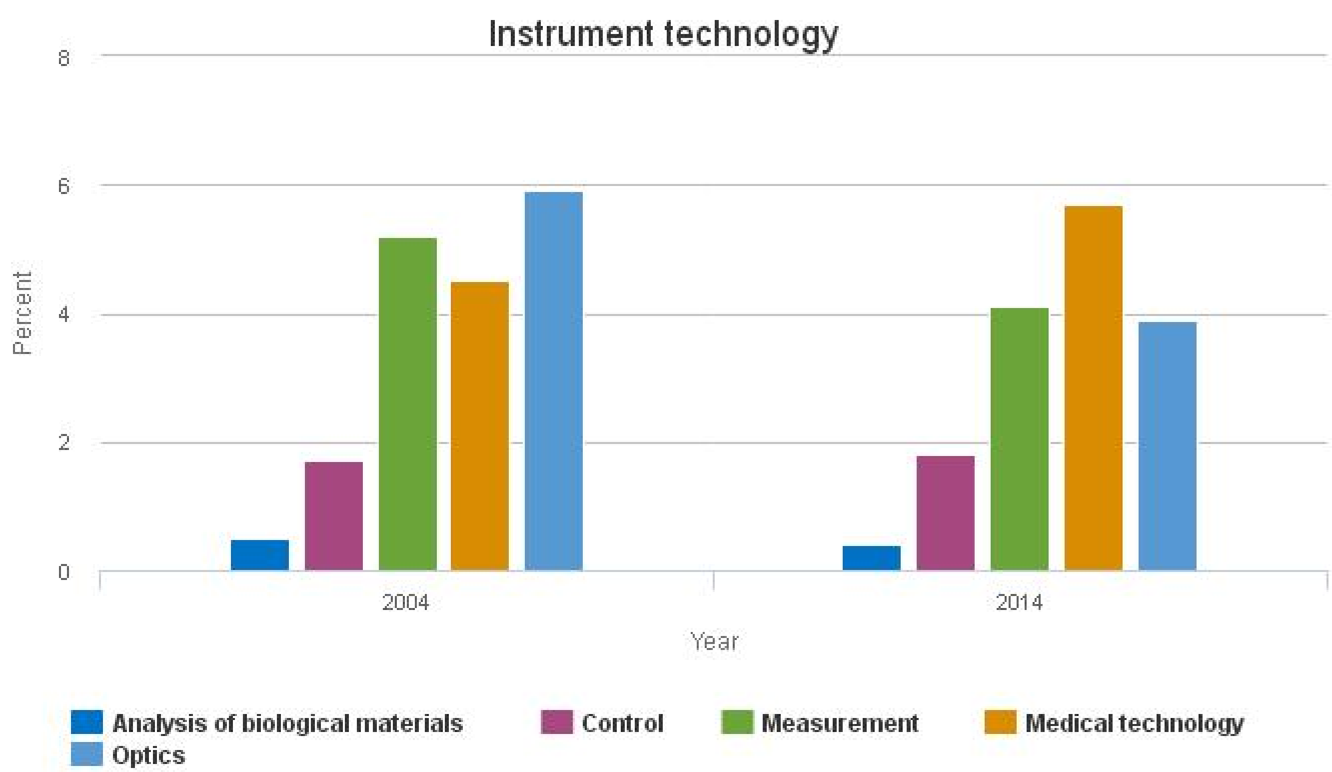
The WIPO classification is similar to The Patent Board™ classification that was used in *SEI 2012* and *SEI 2014*: Each classification has 35 technology fields, and some fields are the same, including biotechnology, pharmaceuticals, and semiconductors. They have some differences, particularly for ICT fields. The WIPO classification has six ICT technology fields—basic communication processes, computer technology, digital communication, information technology methods for management, semiconductors, and telecommunications. The Patent Board™ classification has five fields—computer systems, information processing, networking, semiconductors, and telecommunications. Importantly, the WIPO classification is freely available to researchers, policymakers, and others who wish to independently verify results or conduct their own research.

Figure 6-27

USPTO patents granted in selected technology categories: 2004 and 2014





ICT = information and communications technology; IT = information technology; USPTO = U.S. Patent and Trademark Office.

NOTES: Patents are classified by the World Intellectual Property Organization's (WIPO's) classification of patents, which classifies International Patent Classification (IPC) codes under 35 technical fields. IPC reformed codes, which take into account changes that were made to the WIPO classification in 2006 under the eighth version of the classification, were used to prepare these data. Fractional counts of patents were assigned to each IPC code on patents to assign the proper weight of a patent to the corresponding IPC codes and their associated technical fields under the classification. Patents are fractionally allocated among regions/countries/economies based on the proportion of residences of all named inventors.

SOURCES: Science-Metrix, LexisNexis, and SRI International. See appendix tables 6-37–6-48.

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The instruments category also has a significant share of USPTO patents (16%) (Figure 6-27; Appendix Table 6-44, Appendix Table 6-45, Appendix Table 6-46, Appendix Table 6-47, and Appendix Table 6-48). Medical technology has the largest share (6%), followed by measurement and optics, which each have a 4% share.

Biotechnology and pharmaceuticals each have a 2%–3% share (Appendix Table 6-49 and Appendix Table 6-50).

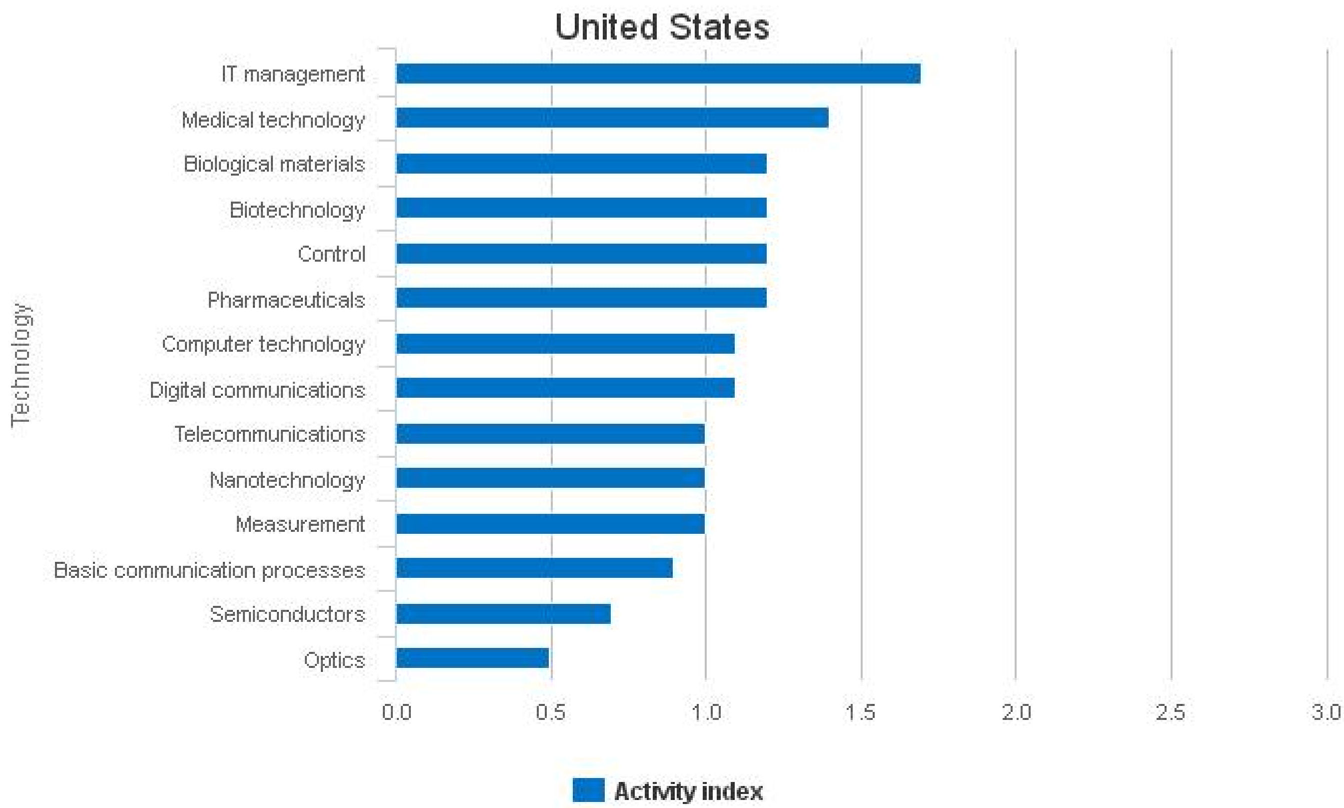
Activity of Major Patenting Regions and Countries in Selected Technology Areas

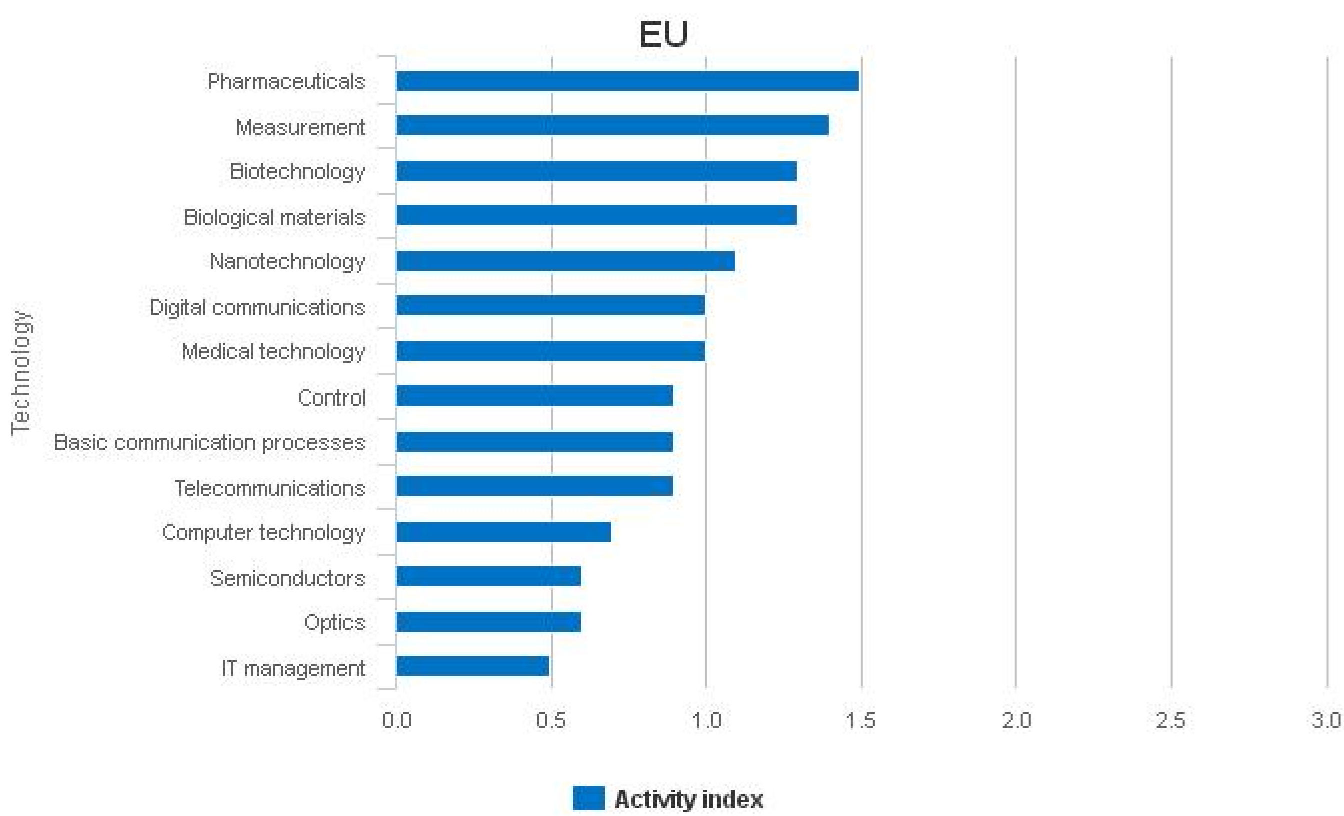
This section presents the *patent activity indexes* of the United States, the EU, and several Asian countries in these technology areas averaged for 2012–14. A patent activity index is the ratio of a country's share of a technology to its share of all patents. A patent activity index greater than one indicates that the country is relatively more active in the technology area.

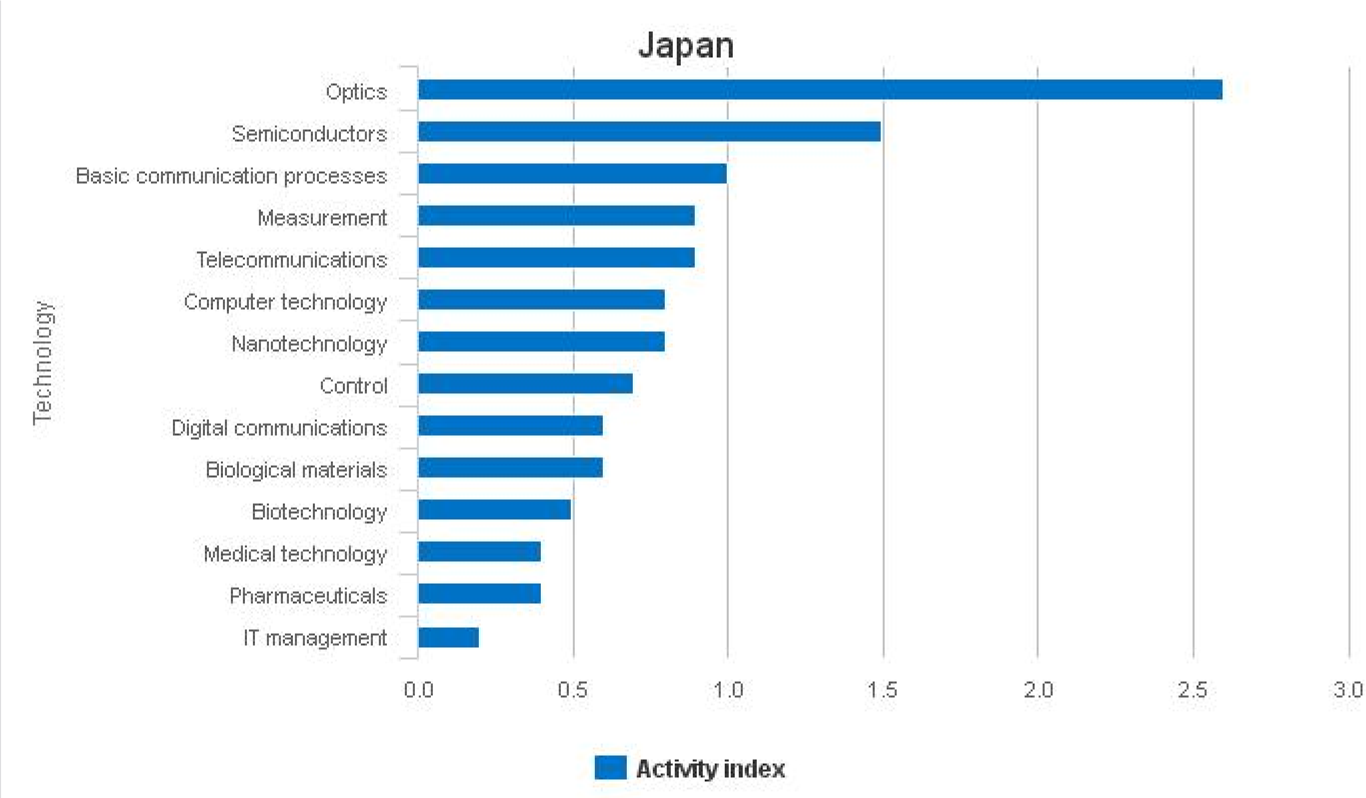
The United States is relatively more active in three ICTs: IT management, computer technology, and digital communications (Figure 6-28). It is particularly active in IT management with an index of 1.7. In the instruments category, the United Sates is relatively more active in medical technology, biological materials, and control, which may reflect its strong market position in the HT manufacturing industry of scientific instruments and measuring equipment. The United States also has greater-than-average activity in biotechnology and pharmaceuticals, consistent with its strong market position in the pharmaceuticals industry. The United States has relatively weaker activity in semiconductors and basic communications processes. Its index is very low in optics, which is part of the instruments technology category.

Figure 6-28

Patent activity index of selected technologies for the United States, the EU, and Japan: 2012–14







EU = European Union; IT = information technology.

NOTES: A patent activity index is the ratio of a country's share of a technology area to its share of all patents. A patent activity index greater (less) than 1.0 indicates that the country is relatively more (less) active in the technology area. Patents are classified by the World Intellectual Property Organization's (WIPO's) classification of patents, which classifies International Patent Classification (IPC) codes under 35 technical fields. IPC reformed codes, which take into account changes that were made to the WIPO classification in 2006 under the eighth version of the classification, were used to prepare these data. Fractional counts of patents were assigned to each IPC code on patents to assign the proper weight of a patent to the corresponding IPC codes and their associated technical fields under the classification. Patents are fractionally allocated among regions/countries/economies based on the proportion of residences of all named inventors.

SOURCES: Science-Metrix, LexisNexis, and SRI International.

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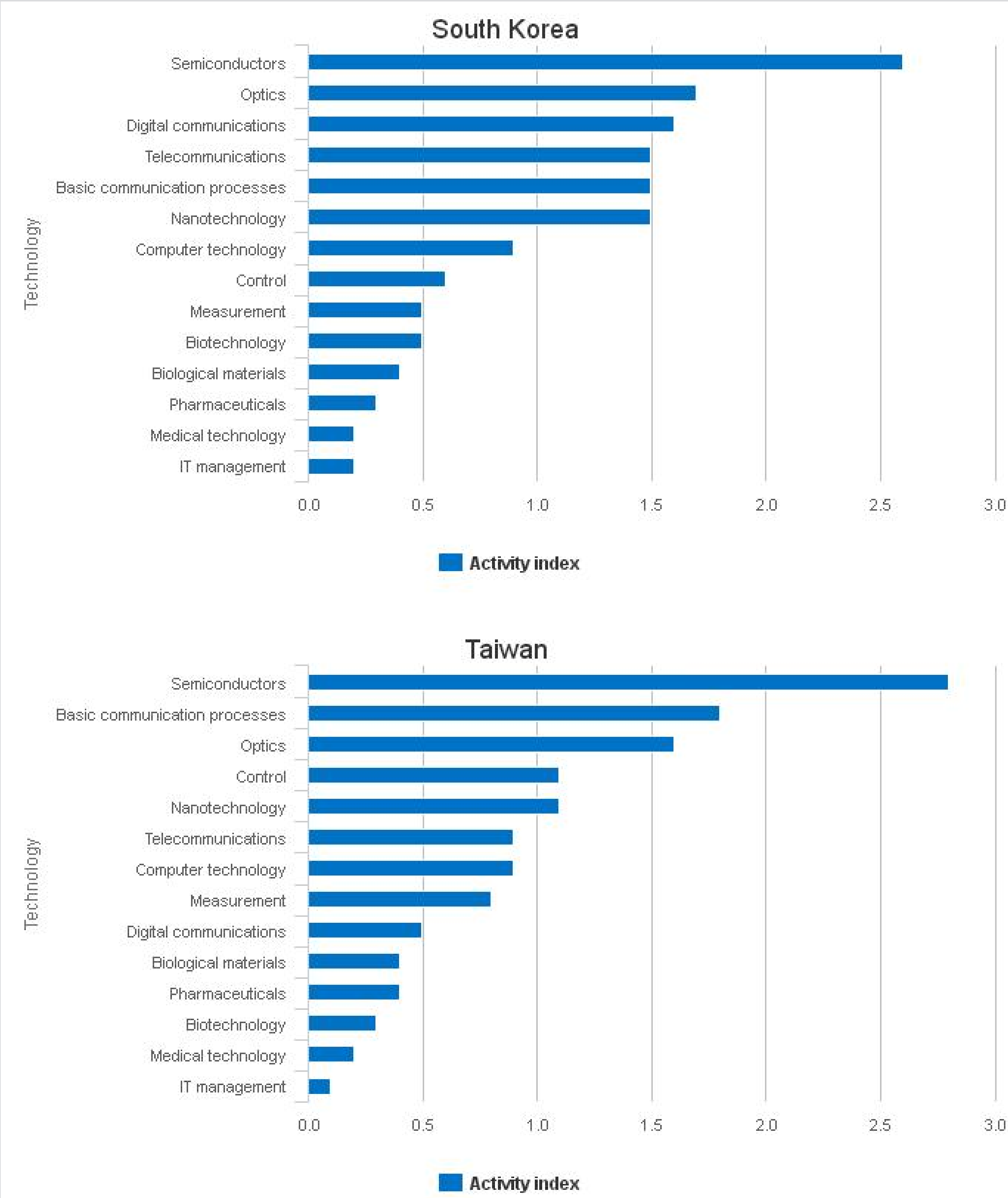
The EU's patenting is average or relatively less active in most technologies (Figure 6-28). It is relatively more active in two instrument technologies—measurement and biological materials—which may reflect its strong market position in the scientific measuring and instruments industry. The EU also is very active in pharmaceuticals (1.5) and biotechnology (1.3), which likely reflect its strong market position in pharmaceuticals.

Japan has a similar profile to the EU with average or relatively less patenting activity in most technologies (Figure 6-28). Japan has very high activity in optics and is high in semiconductors. South Korea and Taiwan have very high activity indexes in semiconductors and optics (Figure 6-29). They also have high relative activity in basic communication processes. South Korea is also active in telecommunications.

Figure 6-29

Patent activity index of selected technologies for South Korea and Taiwan: 2012–14



IT = information technology.

NOTES: A patent activity index is the ratio of a country's share of a technology area to its share of all patents. A patent activity index greater (less) than 1.0 indicates that the country is relatively more (less) active in the technology area. Patents are classified by the World Intellectual Property Organization's (WIPO's) classification of patents, which classifies International Patent Classification (IPC) codes under 35 technical fields. IPC reformed codes, which take into account changes that were made to the WIPO classification in 2006 under the eighth version of the classification, were used to prepare these data. Fractional counts of patents were assigned to each IPC code on patents to assign the proper weight of a patent to the corresponding IPC codes and their associated technical fields under the classification. Patents are fractionally allocated among regions/countries/economies based on the proportion of residences of all named inventors.

SOURCES: Science-Metrix, LexisNexis, and SRI International.

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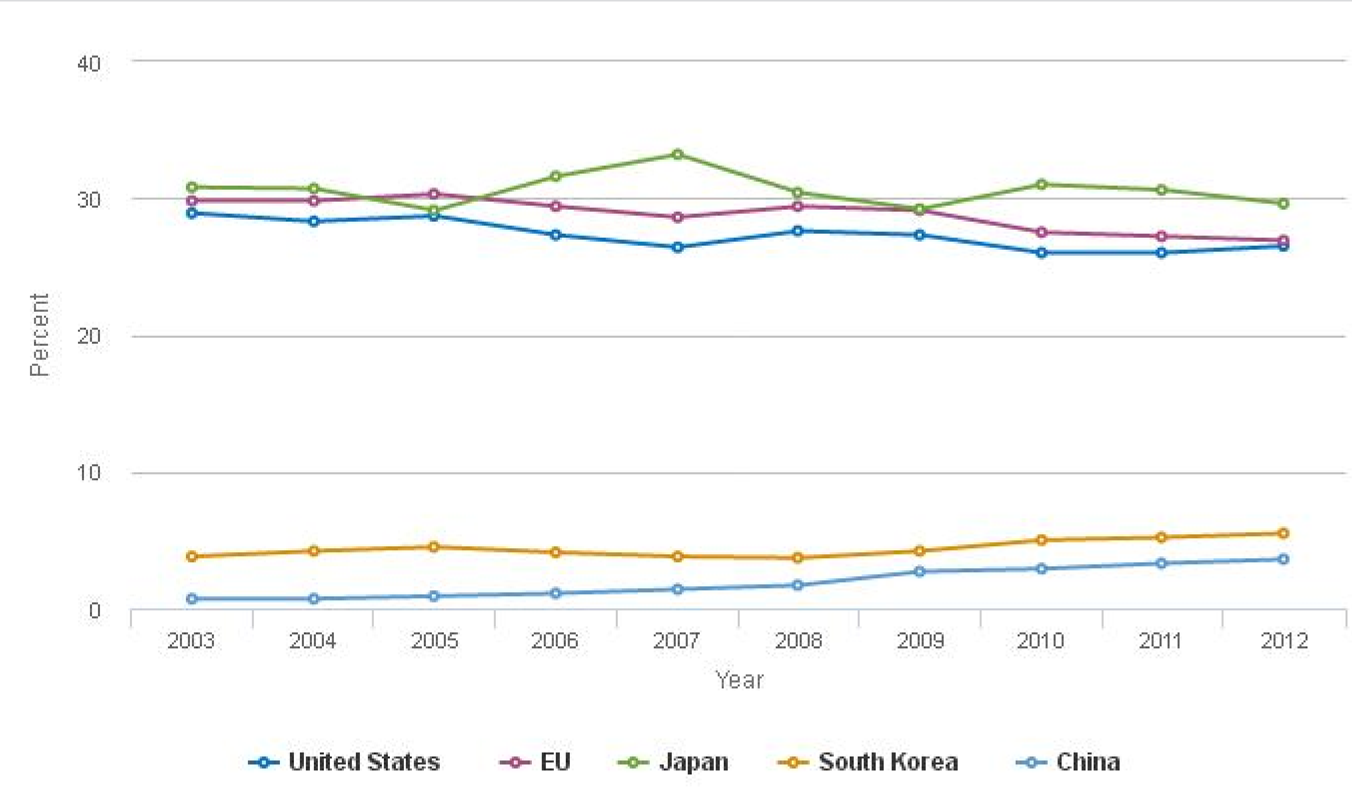
Patenting Valuable Inventions: Triadic Patents

Using counts from a national patent office as an indicator of inventive activity may not differentiate between inventions of minor and substantial economic potential. Inventions for which patent protection is sought in three of the world's largest markets—the United States, Europe, and Japan—are likely to be viewed by their owners as justifying the high costs of filing and maintaining these patents in three markets. These *triadic patents* serve as an indicator of higher-value inventions, although growing patent activity in China, India, South Korea, and other locations may limit the utility of this measure. The number of triadic patents is strongly correlated with expenditures on industry R&D, suggesting that countries with higher patenting activity make greater investments to foster innovation (OECD 2009:36).

Japan is the leading recipient of triadic patents with a share of 30% (Figure 6-30; Appendix Table 6-51). The EU and United States are tied at second with shares each of 26%–27%.

Figure 6-30

Global triadic patent families, by selected region/country/economy: 2003–12



EU = European Union.

NOTES: Triadic patent families include patents all filed together at the European Patent Office and Japan Patent Office and granted at the U.S. Patent and Trademark Office, protecting the same set of inventions. Patent families are fractionally allocated among regions/countries/economies based on the proportion of residences of all named inventors. China includes Hong Kong.

SOURCES: Science-Metrix; SRI International; and Organisation for Economic Co-operation and Development, Patent Statistics, Patents by Technology database, http://stats.oecd.org/Index.aspx?DatasetCode=PATS_IPC, accessed 12 March 2015.

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The shares of the United States and the EU fell slightly over the decade (Figure 6-30; Appendix Table 6-51). Japan's share remained unchanged. South Korea's share rose from 4% to 6%. China's share quadrupled to 4%, consistent with its rapid growth in USPTO patents during this period.

Trade in Royalties and Fees

Firms trade intellectual property, such as patented and unpatented techniques, processes, formulas, and other intangible assets and proprietary rights. These types of transactions generate revenues in the form of royalties and licensing fees. Trade in royalties and fees provides a broad indicator of technology flows across the global economy and the value of an economy's intellectual property in the international marketplace.[i]

Global exports of royalties and fees were $255 billion in 2013 (Figure 6-31; Appendix Table 6-52). The United States was the world's largest exporter of royalties and fees (50% global share) with a substantial trade surplus (Figure 6-31).[ii] The U.S. global export share fell slightly between 2004 and 2013.

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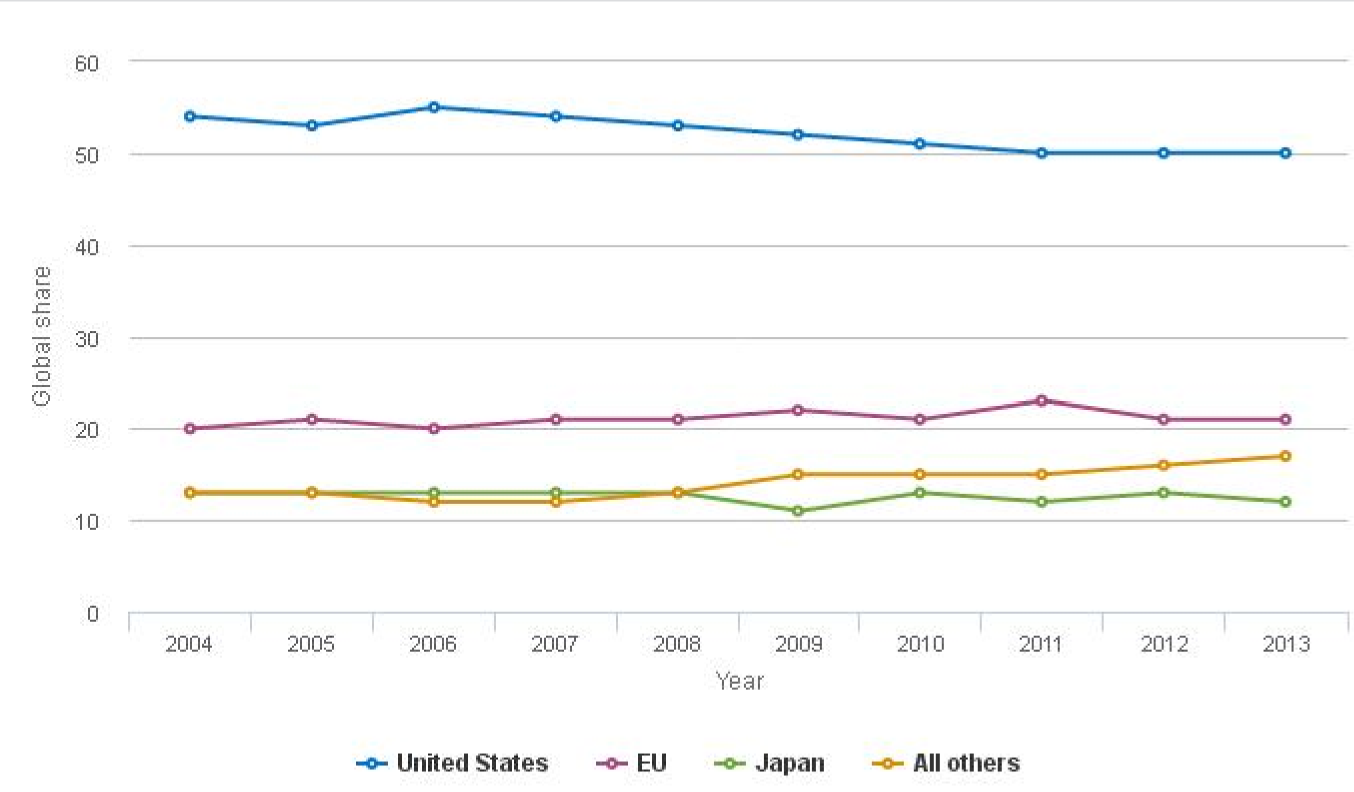
[i] Differences in tax policies and protection of intellectual property also likely influence the volume and geographic patterns of global trade in royalties and fees (Gravelle 2010:8; Mutti and Grubert 2007:112).

[ii] The volume and geographic patterns of U.S. trade in royalties and fees have been influenced by U.S.-based multinationals transferring their intellectual property to low-tax jurisdictions or their foreign subsidiaries to reduce their U.S. and foreign taxes (Gravelle 2010:8; Mutti and Grubert 2007:112).

Figure 6-31

Exports of royalties and fees, by selected region/country/economy: 2004–13



EU = European Union.

NOTE: EU exports do not include intra-EU exports.

SOURCE: World Trade Organization, International trade and tariff data, http://www.wto.org/english/res_e/statis_e/statis_e.htm, accessed 15 February 2015.

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The EU is the second largest, with a global share of 21%, but it has a small deficit in trade of royalties and fees. Japan, the third largest (12% share), has a substantial trade surplus. The global shares of the EU and Japan were stable over the last decade.

Exports of developing countries are very low; for example, the global shares of China and India were less than 1% in 2014.

Venture Capital and Small Business Innovation Research Investment

Entrepreneurs seeking to start or expand a small firm with new or unproven technology may not have access to public or credit-oriented institutional funding. Often, entrepreneurs rely on friends and family for financing. However, when they need or can get access to larger amounts of financing, venture capital investment is often critical to financing nascent and emerging HT businesses. This section will examine patterns and trends of venture capital financing in the United States and internationally and Small Business Innovation Research (SBIR) investment in the United States.[i]

Venture capital investment. Global venture capital investment was $79 billion in 2014. The United States attracted the most venture capital ($49 billion) of any region/country (Figure 6-32; Appendix Table 6-53). China was second ($13 billion), followed by Europe ($9 billion) and India ($5 billion) (Figure 6-33).

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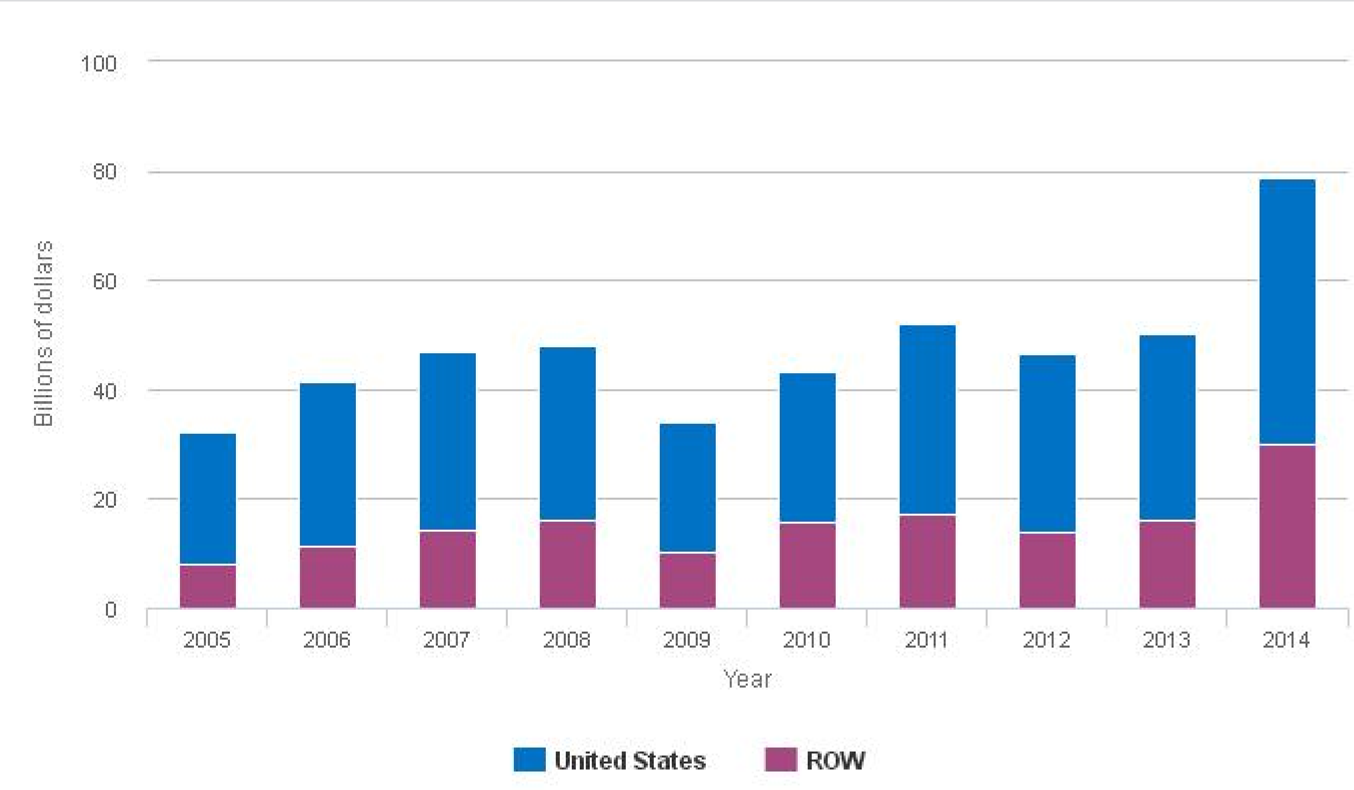
[i] In this section, business denotes anything from an entrepreneur with an idea to a legally established operating company.

Figure 6-32

Venture capital investment in the United States and the rest of the world: 2005–14



ROW = rest of world.

NOTE: ROW includes Canada, China, Europe, India, and Israel.

SOURCE: Dow Jones, special tabulations (2015) from VentureSource database, http://www.dowjones.com/info/venture-capital-data.asp, accessed 15 March 2015.

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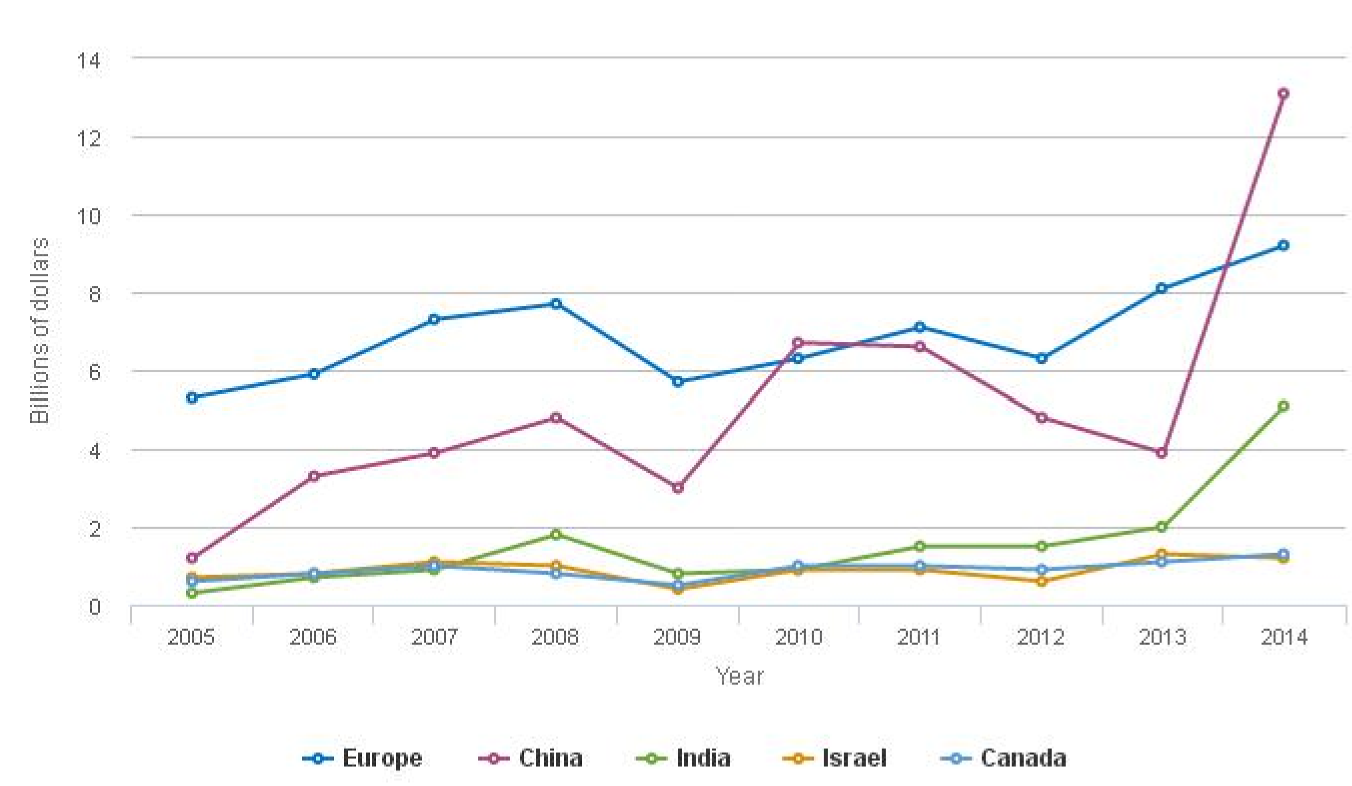
Figure 6-33

Venture capital investment, by selected region/country/economy: 2005–14



SOURCE: Dow Jones, special tabulations (2015) from VentureSource database, http://www.dowjones.com/info/venture-capital-data.asp, accessed 15 March 2015.

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Between 2005 and 2013, global venture capital investment remained in the range of $32 billion to $50 billion before surging to $79 billion in 2014, a 57% increase from 2013 (Figure 6-32). The jump in global investment occurred across all regions and countries, led by the United States and China. Investment in the United States reached $49 billion, its highest level since the 2000 dot-com bubble's $87 billion. China's venture capital investment jumped from $4 billion in 2013 to $13 billion in 2014 (Figure 6-33).

Faster venture capital growth overseas over the past decade reduced the U.S. global share from 75% in 2005 to 62% in 2014 (Figure 6-32). The expansion of venture capital outside of the United States coincides with the globalization of finance, greater commercial opportunities in rapidly growing developing countries, and the decline of yields on existing venture capital investments in U.S. companies.[ii] In China, venture capital grew from $1 billion in 2005 to $13 billion in 2014, resulting in its global share reaching 17% (Figure 6-33). India's share of global investment grew from 1% to 6%.

Venture capital investment is generally categorized into four broad stages of financing:

- *Seed* supports proof-of-concept development and initial product development and marketing.
- *First round* supports product development and marketing and the initiation of commercial manufacturing and sales.

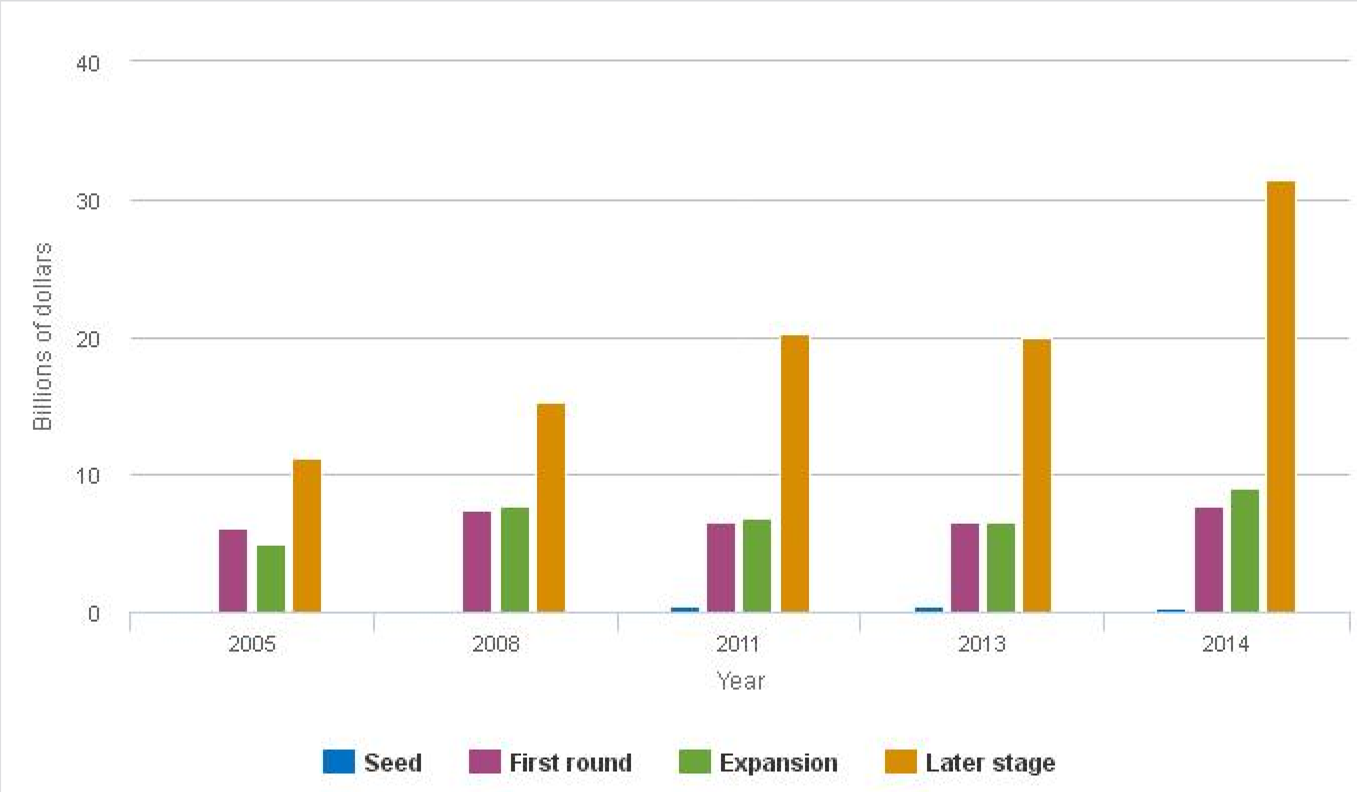
- *Expansion* provides working capital for company expansion, funds for major growth (including plant expansion, marketing, or developing an improved product), and financing to prepare for an initial public offering (IPO).
- *Later stage* includes acquisition financing and management and leveraged buyouts. Acquisition financing provides resources for the purchase of another company, and management and leveraged buyouts provide funds to enable operating management to acquire a product line or business from either a public or a private company.

Venture capital investment has become more concentrated in later stages over the past decade. Observers have attributed this shift to a desire to lower investment risk, a decline in yields on existing earlier stage investments, and a sharp decline in IPOs and acquisitions of firms backed by venture capital, requiring venture capital investors to commit additional resources in the face of lower returns. In 2014, later stage venture capital invested in the United States comprised 65% of total investment, up from 50% in 2005 (Figure 6-34; Appendix Table 6-53). The first round share especially, and the expansion share, declined during this period.

[ii] Another possibility is that the behavior of venture capital investors changed because fewer opportunities for attractive risky investments were available in the 2000s than in the 1990s.

Figure 6-34

U.S. venture capital investment, by financing stage: Selected years, 2005–14



NOTES: Seed stage consists of proof-of-concept development and initial product development and marketing. First round consists of product development and marketing and the initiation of commercial manufacturing and sales. Expansion consists of second-round financing that provides working capital for company expansion and financing to prepare for an initial public offering. Later stage includes acquisition financing and management and leverage buyouts.

SOURCE: Dow Jones, special tabulations (2015) from VentureSource database, http://www.dowjones.com/info/venture-capital-data.asp, accessed 15 March 2015. See appendix table 6-53.

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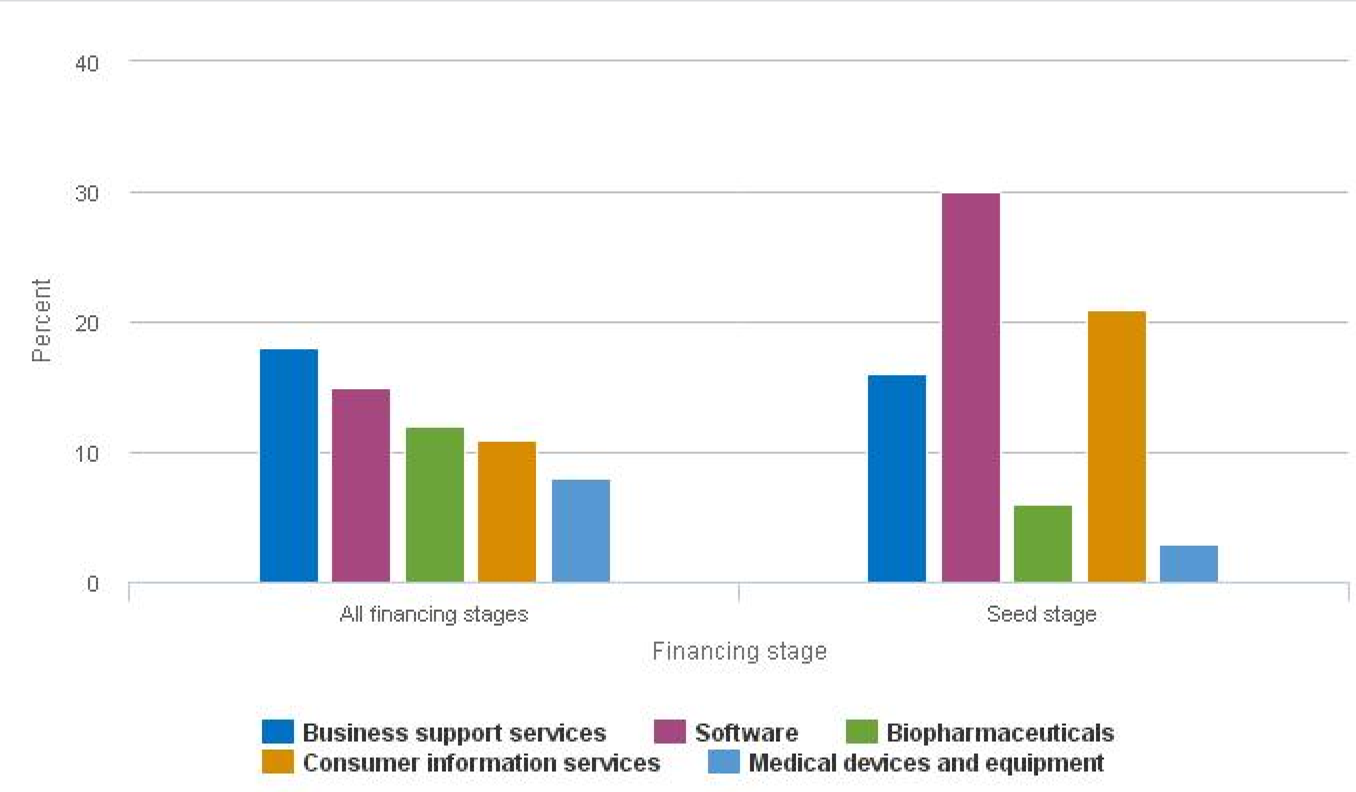
Investment in the seed stage, the earliest stage, has remained at 1% or less of total U.S. venture capital investment over the last decade (Figure 6-34; Appendix Table 6-53). Despite the jump in total U.S. venture capital investment between 2013 and 2014, investment in the seed stage fell from $354 million to $279 million. Researchers and observers have expressed concern that the lack of early stage venture capital financing contributes to the “valley of the death,” the inability of new and nascent firms to obtain financing to commercialize their inventions and technology.

Five technologies—biopharmaceuticals, business support services, consumer information services, medical devices and equipment, and software—have dominated U.S. venture capital investment during 2011–14 (Figure 6-35; Appendix Table 6-53):

Figure 6-35

U.S. venture capital investment, by selected financing stage and technology/industry: 2011–14



NOTES: Technologies are classified by Dow Jones. Seed stage consists of proof-of-concept development and initial product development and marketing.

SOURCE: Dow Jones, special tabulations (2015) from VentureSource database, http://www.dowjones.com/info/venture-capital-data.asp, accessed 15 March 2015. See appendix table 6-53.

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- Business support services led these technologies in venture capital investment, receiving 18% of total investment in 2011–14. This technology area also received a significant share of seed investment (16%).
- Software had the second highest share of total investment (15%) and attracted the most seed investment of any technology (30%).
- Biopharmaceuticals was third, accounting for 12% of total investment and 6% of seed investment.
- Consumer information services closely followed biopharmaceuticals, receiving 11% of total investment. This technology had the second highest share in seed investment (21%).
- Medical devices and equipment was the fifth-largest technology, accounting for 8% of total investment and 3% of seed investment.

SBIR investment. The U.S. government's SBIR program provides early stage public financing to help U.S. small or start-up companies to commercialize technology derived from federal R&D.[iii] The SBIR program provides financing in two phases:

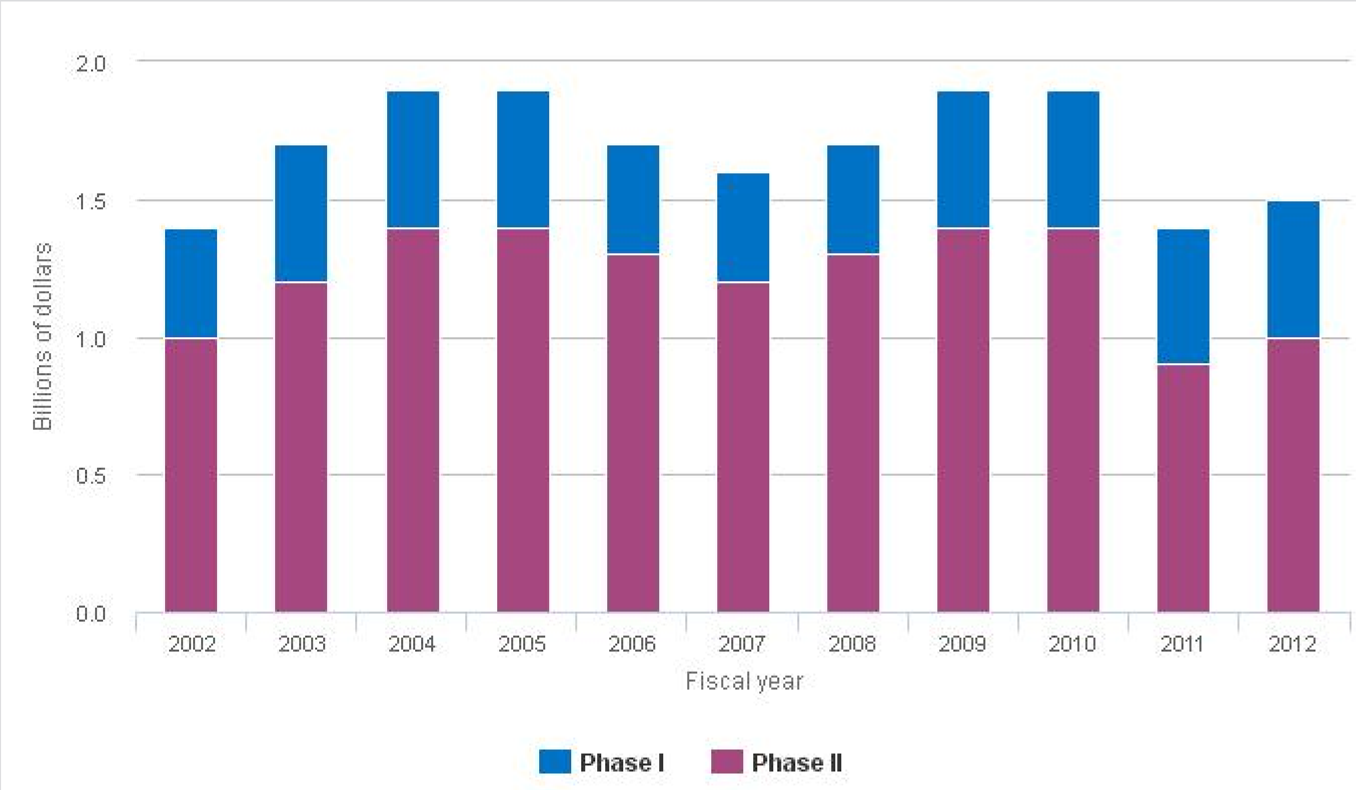
- Phase I funds the evaluation of the scientific and technical merit and feasibility of a company's new ideas.
- Phase II funds further scientific and technical review and requires a commercialization plan.

SBIR provided $1.5 billion in early stage financing in FY 2012, more than fivefold the amount of seed stage venture capital (Figure 6-36). The U.S. Departments of Defense and Health and Human Services provide the bulk of SBIR financing (almost 80% of total SBIR funding) with smaller amounts from the Department of Energy, the National Aeronautics and Space Administration, and NSF (Figure 6-37). Most SBIR financing occurs in Phase II, which provided $1.0 billion to fund 2,000 awards in FY 2012. Phase I provided $0.5 billion for 3,500 awards.

[iii] For more information on SBIR, see chapter 4 .

Figure 6-36

SBIR investment, by financing phase: FYs 2002–12



SBIR = Small Business Innovation Research program.

NOTES: SBIR investment is by fiscal year. Investment is the amount obligated by U.S. federal agencies for SBIR financing. Phase I evaluates the scientific and technical merit and feasibility of ideas. Phase II is subject to further scientific and technical review and requires a commercialization plan.

SOURCE: SBIR Annual Report data, http://www.sbir.gov/awards/annual-reports, accessed 15 May 2015.

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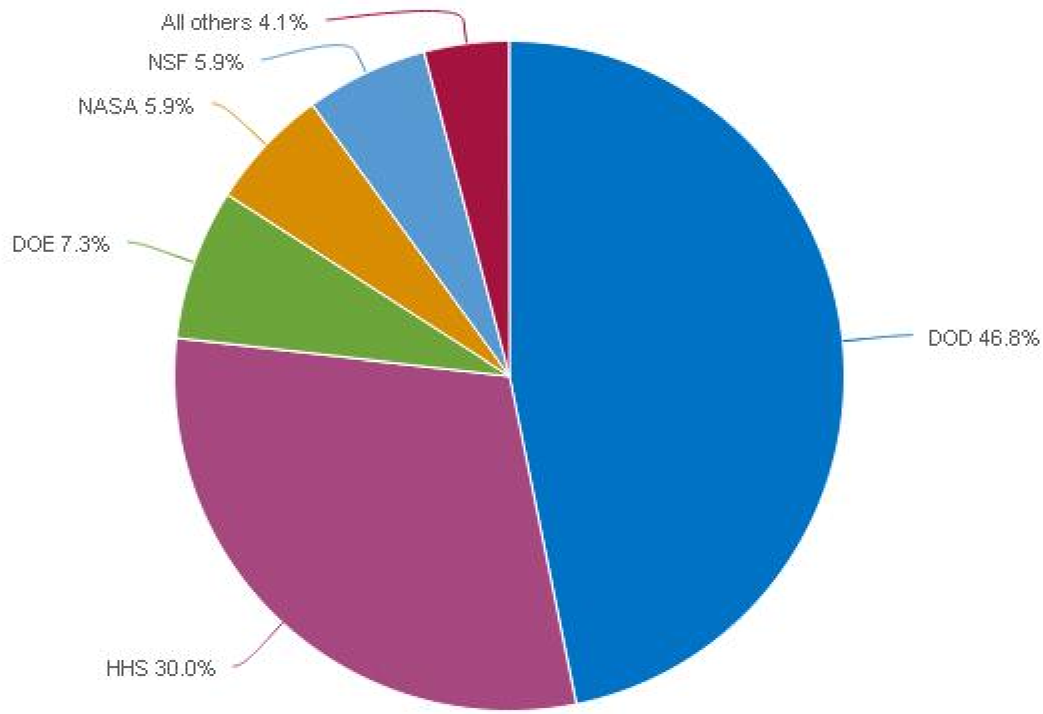
Figure 6-37

SBIR funding, by share of selected federal agency: FYs 2010–12



DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; SBIR = Small Business Innovation Research program.

NOTES: Funding is budget obligations for each federal agency. All others includes Department of Commerce, Department of Education, Department of Homeland Security, Department of Transportation, Environmental Protection Agency, and U.S. Department of Agriculture.

SOURCE: SBIR Annual Report data, http://www.sbir.gov/awards/annual-reports, accessed 15 May 2015.

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SBIR financing was relatively stable in FYs 2003–10 before falling sharply (more than 25%) in FYs 2011–12 because of declines in Phase II funding (Figure 6-36). The decline was due to cutbacks in research funding as part of reduced government spending after the 2008–09 recession.[iv] In FY 2012, SBIR provided $1.0 billion for nearly 2,000 Phase II awards compared with $1.4 billion awarded to 1,800 companies in FY 2010. The recent sharp decline in SBIR financing may be of concern given that some researchers and policymakers believe that the United States lacks sufficient capital to finance small or start-up companies seeking to commercialize their technologies.

[iv] SBIR is funded through a fixed percentage (typically 2.5%) of the sponsoring agencies' overall research budget.

Investment and Innovation in Clean Energy Technologies

This section is devoted to examining clean energy and related technologies. Clean energy, like KTI industries, has a strong link to S&T. Clean energy and related technologies—including biofuels, solar, wind, energy efficiency, pollution prevention, smart grid, and CO_2 sequestration—have become a policy focus in developed and developing countries. These technologies are knowledge and technology intensive and thus closely linked to scientific R&D.

Production, investment, and innovation in these energies and technologies are rapidly growing in many countries in response to rising energy demand, the volatile cost of fossil fuels, and efforts by many countries to reduce their emissions of greenhouse gases. Governments have enacted various policy measures, including subsidies and tax incentives, and have increased funding for energy R&D to spur the development of effective, affordable alternative energy sources.

This section will examine public research, development and demonstration (RD&D) and private investment in clean energy and related technologies. Private investment consists of early stage financing—venture capital and private equity—and later stage financing. The public RD&D data discussed here are not comparable with the energy R&D data described in chapter 4.[i] The public RD&D includes coverage of nuclear energy, which is not covered by the private investment data.

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[i] The International Energy Agency (IEA) manual states: "The IEA concept of Energy RD&D differs from the Frascati concept of R&D, in that (i) it focuses on energy related programmes only; (ii) it includes 'demonstration projects'; and (iii) it includes state owned companies…. The energy RD&D data collected by the IEA should not be confused with the data on government budget appropriations or outlays on R&D (GBAORD) collected by the OECD Directorate for Science, Technology, and Industry for the socio-economic objective 'Production, distribution and rational utilisation of energy'" (IEA 2011:16–17).

Public RD&D Expenditures in Clean Energy and Other Non-Fossil Fuel Technologies

Global government investment in RD&D in clean energy and other non-fossil fuel technologies—renewables, energy efficiency, capture and storage of CO_2, nuclear, fuel cells, and other power and storage technologies—was an estimated $12.7 billion in 2013 (Figure 6-38; Appendix Table 6-54, Appendix Table 6-55, Appendix Table 6-56, Appendix Table 6-57, Appendix Table 6-58, Appendix Table 6-59, Appendix Table 6-60, Appendix Table 6-61, Appendix Table 6-62, and Appendix Table 6-63).[i] Renewables was the largest area, receiving $3.7 billion (Figure 6-39). The next two largest areas were nuclear ($3.4 billion) and energy efficiency ($3.2 billion).

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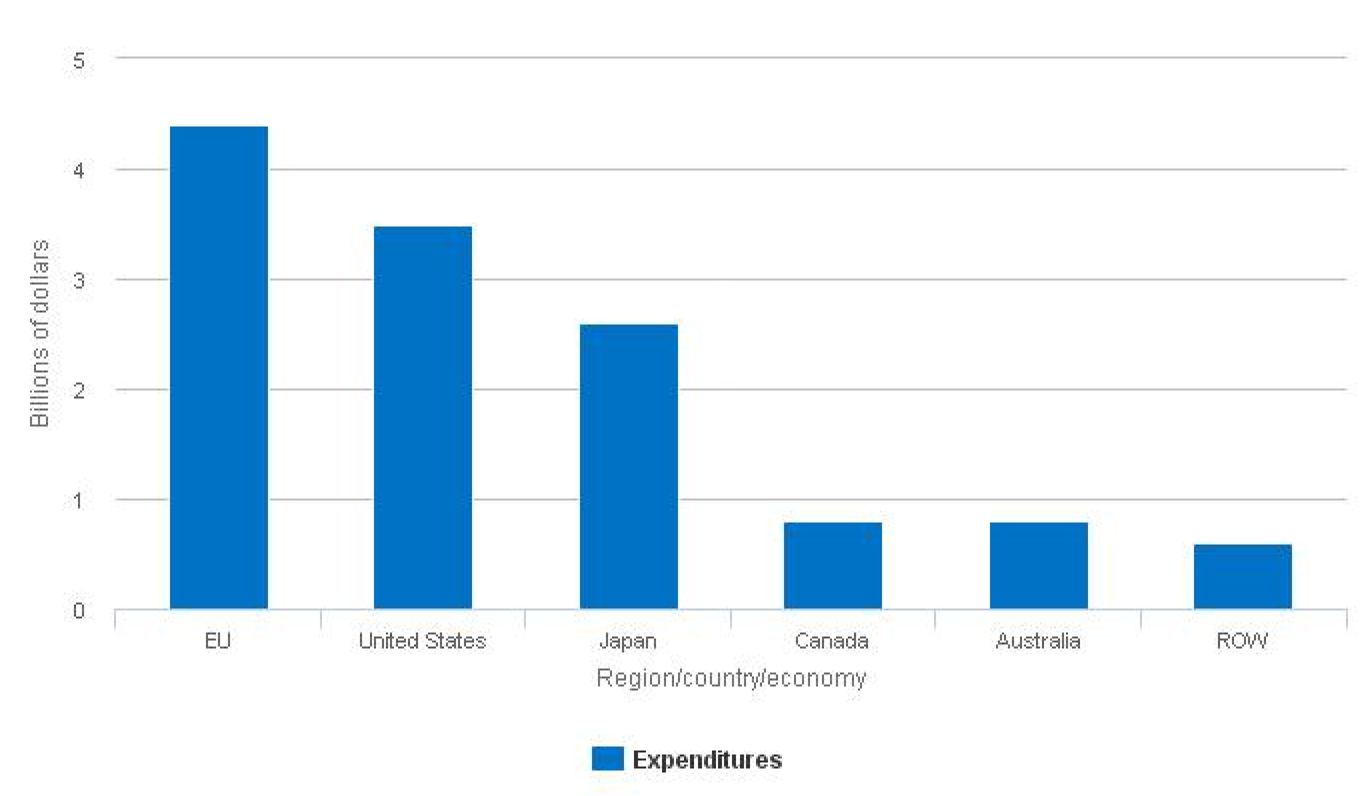
[i] The International Energy Agency has no official definition of clean energy. This discussion includes public research, development, and demonstration in energy efficiency, renewable energy, nuclear, hydrogen and fuel cells, CO_2 capture and storage, and other power and storage technologies.

Figure 6-38

Government RD&D expenditures in clean energy and other non-fossil fuel technologies, by selected region/country/economy: 2013



EU = European Union; RD&D = research, development, and demonstration.

NOTES: Clean energy and other non-fossil fuel technologies include renewables (solar, wind, biofuels, ocean energy, and hydropower), nuclear, hydrogen and fuel cells, CO_2 capture and storage, other power and storage, and energy efficiency. The EU includes Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Spain, Sweden, and the United Kingdom. ROW includes New Zealand, South Korea, and Switzerland.

SOURCES: International Energy Agency, Statistics and Balances, http://www.iea.org/stats/index.asp, accessed 15 February 2015;. See appendix table 6-54.

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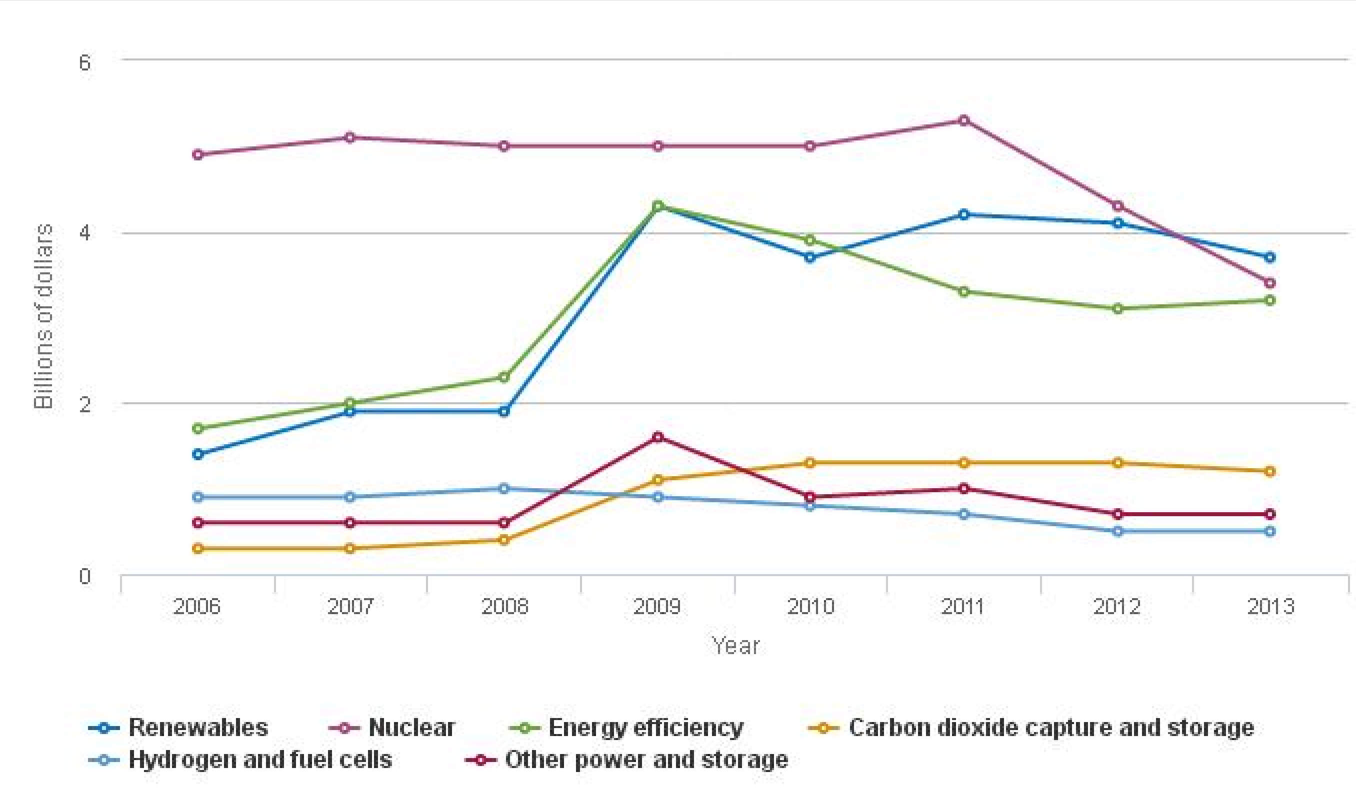
Figure 6-39

Global public RD&D expenditures on clean energy and other non-fossil fuel technologies, by selected technology: 2006–13



RD&D = research, development, and demonstration.

NOTE: Clean energy and other non-fossil fuel technologies include renewables (solar, wind, biofuels, ocean energy, and hydropower), nuclear, hydrogen and fuel cells, CO_2 capture and storage, other power and storage, and energy efficiency.

SOURCES: International Energy Agency, Statistics and Balances, http://www.iea.org/stats/index.asp, accessed 15 February 2015. See appendix tables 6-55–6-63.

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The EU is the largest investor of public RD&D in clean energy and other non-fossil fuel technologies ($4.4 billion), followed by the United States ($3.5 billion) and Japan ($2.6 billion) (Figure 6-38; Appendix Table 6-54). Canada and Australia each spent more than $800 billion.

Public RD&D for clean energy and other non-fossil fuels rose steadily during the 2000s to spike at $17.3 billion in 2009 because of stimulus spending in the United States; it then dropped to $12.7 billion in 2013. Trends among the individual technology areas varied between 2006 and 2013 (Figure 6-39):

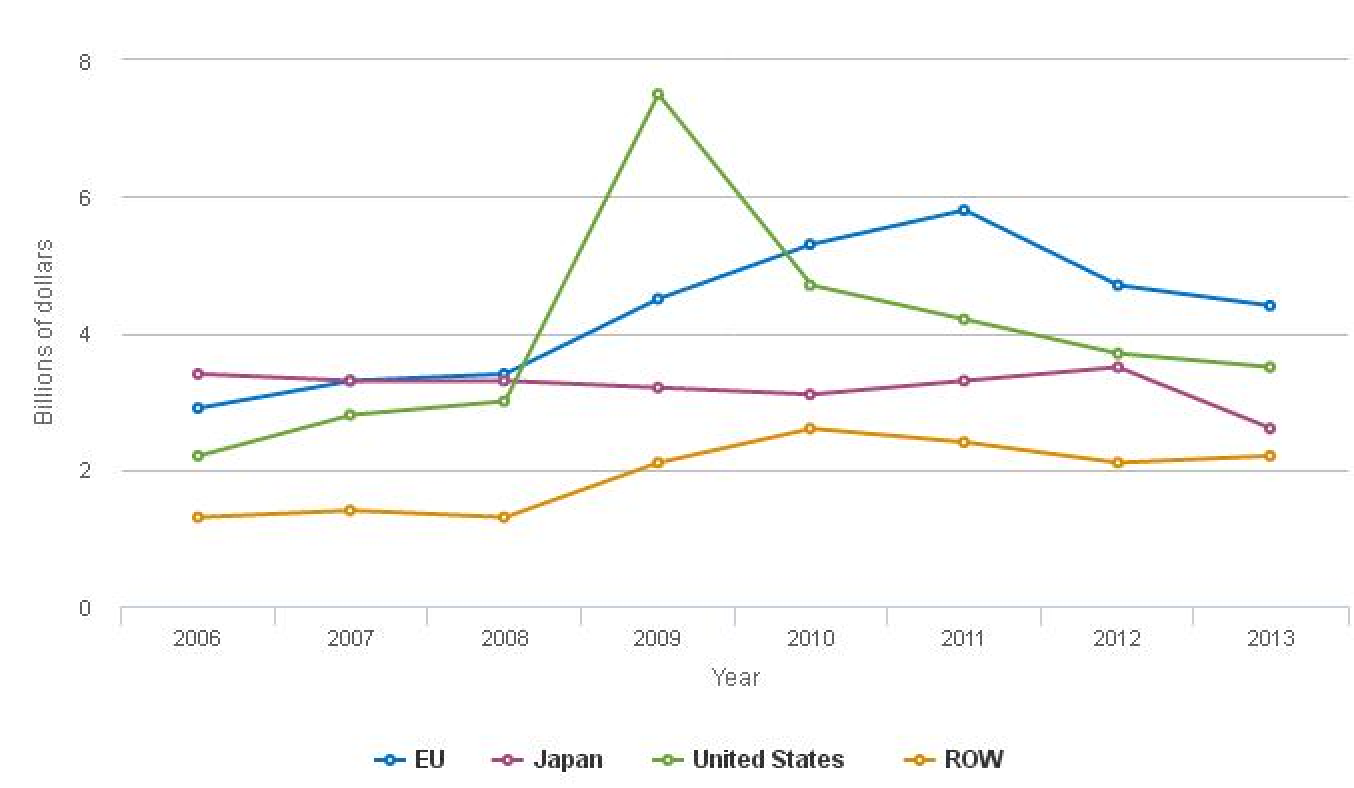
- CO_2 capture and storage had the fastest growth, rising from $300 million to $1.2 billion (Appendix Table 6-62).
- Renewable energy nearly tripled to $3.7 billion (Appendix Table 6-58).
- Energy efficiency nearly doubled to $3.2 billion (Appendix Table 6-56).
- Nuclear energy contracted by 30% to reach $3.4 billion (Appendix Table 6-55).

The United States and the EU led the worldwide growth in public RD&D (Figure 6-40). U.S. RD&D followed a modest upward trend, interrupted by a spike and subsequent decline related to the American Recovery and Reinvestment Act of 2009. U.S. expenditures on energy efficiency and renewables each reached $1.3 and $1.0 billion, respectively (Appendix Table 6-56, and Appendix Table 6-58).

After rising steadily between 2006 and 2011 to reach $5.8 billion, EU investment declined to $4.4 billion in 2013 (Figure 6-40). Japan's investment fell because of a decline in nuclear energy investment (Appendix Table 6-55).

Figure 6-40

Public RD&D on clean energy and other non-fossil fuel technologies, by selected region/country /economy: 2006–13



EU = European Union; RD&D = research, development, and demonstration; ROW = rest of world.

NOTES: Clean energy and other non-fossil fuel technologies include renewables (solar, wind, biofuels, ocean energy, and hydropower), nuclear, hydrogen and fuel cells, CO_2 capture and storage, other power and storage, and energy efficiency. The EU includes Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Spain, Sweden, and the United Kingdom. ROW includes Australia, Canada, Norway, and Switzerland.

SOURCES: International Energy Agency, Statistics and Balances, http://www.iea.org/stats/index.asp, accessed 15 February 2015. See appendix table 6-54.

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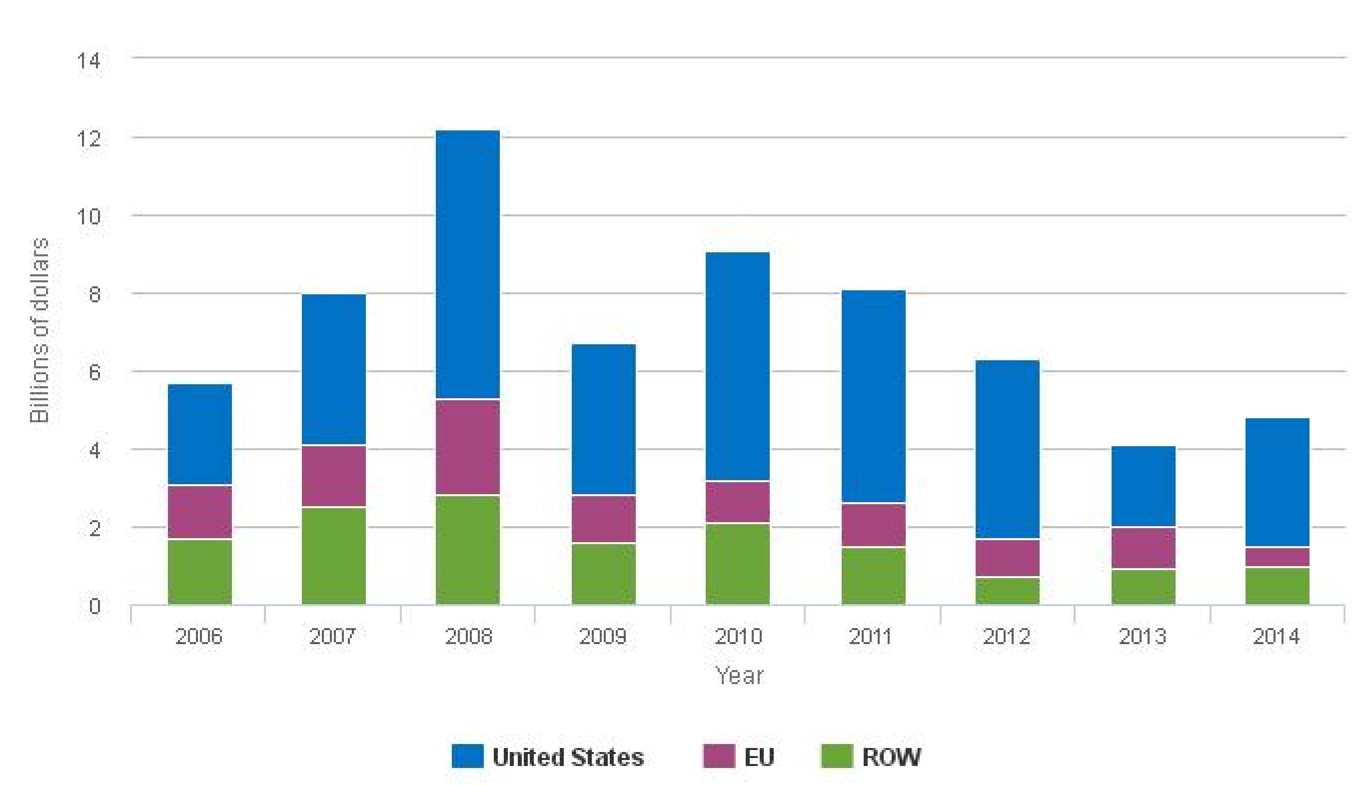
Early Stage Private Financing of Clean Energy

Two types of early stage financing, venture capital and private equity investment, are useful indicators of market assessment of nascent and future trends in clean energy technologies. Global venture capital and private equity investment in clean energy was $4.8 billion in 2014, comprising 2% of commercial financial investment (Figure 6-41). The United States attracted the most venture capital and private equity of any country ($3.3 billion).

Figure 6-41

Global venture capital and private equity investment in clean energy technologies, by selected region/country: 2006–14



EU = European Union; ROW = rest of world.

NOTE: Clean energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2014).

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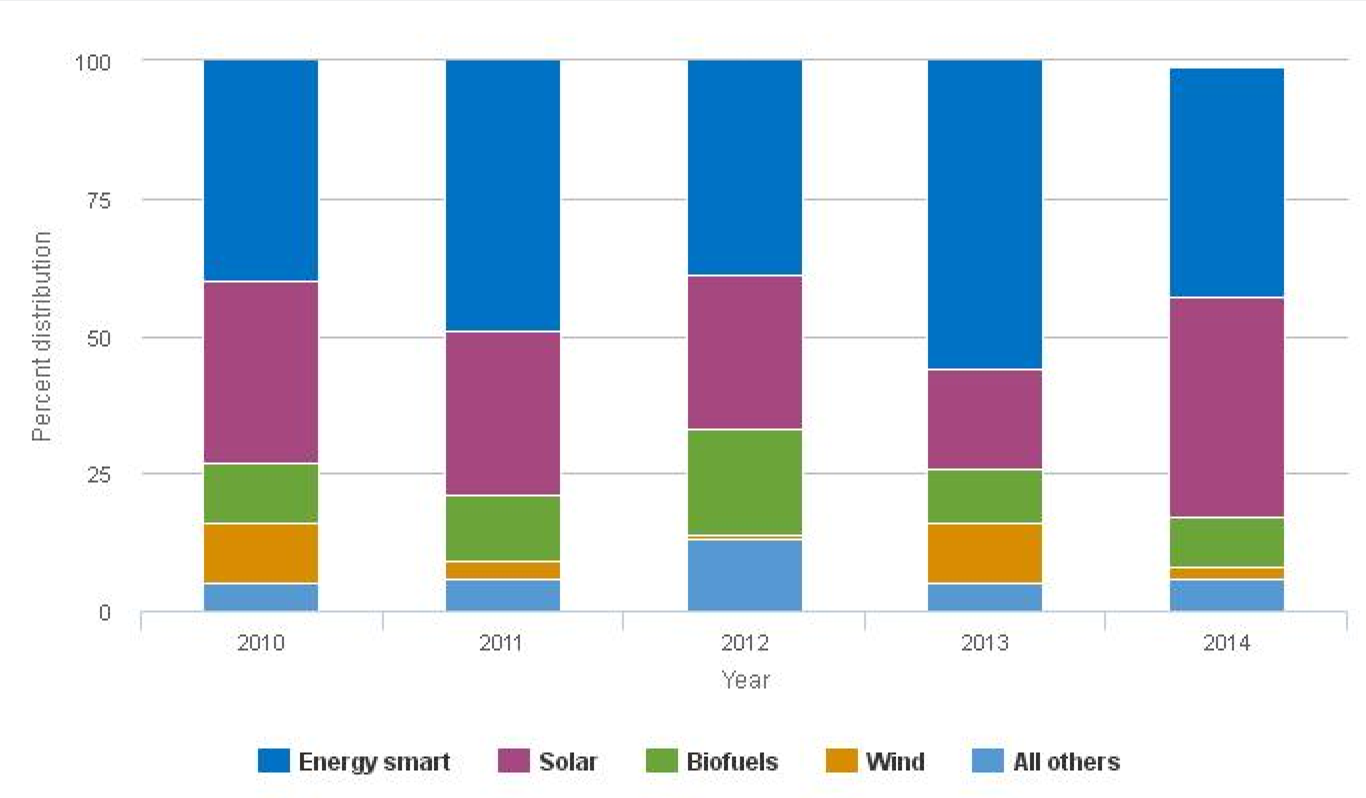
After peaking at an all-time high of $12.3 billion in 2008, global investment plunged to $4.2 billion in 2013 before increasing to $4.8 billion in 2014. The fall-off in investment during 2009–14 has been attributed to the difficulty of venture capitalists raising new funds and the lack of successful exits for existing venture-backed clean energy companies.

U.S. venture capital and private equity investment has paralleled the trend of global investment over the last decade. The jump in investment between 2013 and 2014 was driven largely by a $1 billion increase in solar investment (Figure 6-41). Over the last 5 years, energy smart has been the largest technology area, accounting for an average 46% share between 2010 and 2014 (Figure 6-42).

Figure 6-42

U.S. venture capital and private equity investment in clean energy technologies, by selected technology: 2010–14



NOTE: Clean energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2014).

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The energy smart category covers a wide range of technologies, from digital energy applications to efficient lighting, electric vehicles, and the smart grid that maximizes the energy efficiency of existing energy sources and networks. Several factors account for the popularity of energy smart technologies. They (1) are less capital intensive than other clean energy technologies, (2) give a shorter time horizon than most other energy technologies, (3) can be applied to a wider range of energy products and services, and (4) are less reliant on government incentives or subsidies.

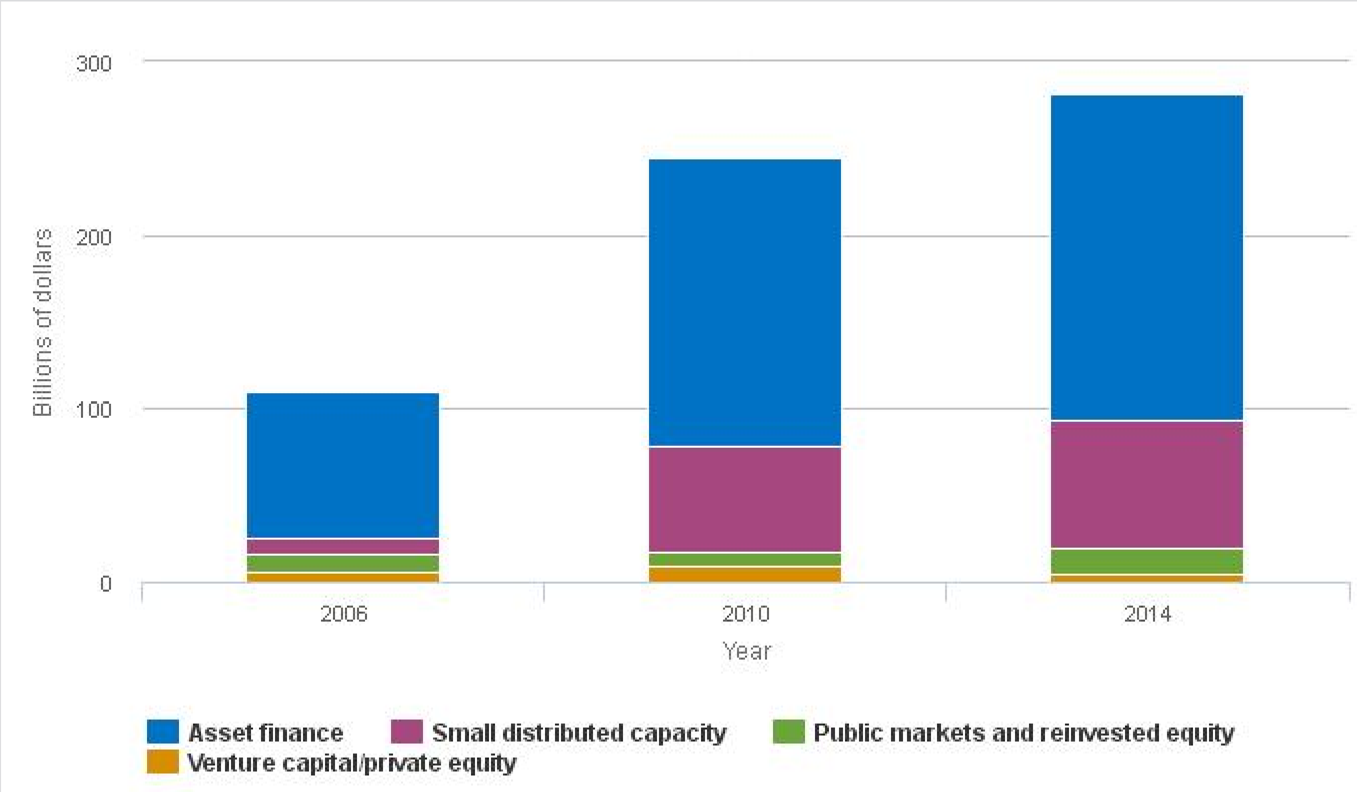
Solar is the second-largest technology area, accounting for 30% of investment over the last 5 years. Biofuels is the third-largest area (12% share).

Private Investment in Clean Energy Technologies

Private investment in clean energy technologies consists of early stage financing, venture capital and private equity, later stage financing, and asset finance—capital based on future expected income streams, public markets, reinvested equity, and small distributed capacity—installation of photovoltaics on commercial and residential structures (Figure 6-43). Asset finance and small-distributed capacity are by far the largest financing mechanisms of clean energy.

Figure 6-43

Private investment in clean energy technologies, by type of financing: 2006, 2010, and 2014



NOTES: Clean energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies. Private investment includes asset finance, small distributed capacity, venture capital, private equity, reinvested equity, and public markets. Mergers and acquisitions are excluded.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2014).

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Global private investment in clean energy technologies was $281 billion in 2014 (Figure 6-44).[i] Two technologies—wind and solar—dominate clean energy investment, with a combined share of 86% (Figure 6-45). Energy smart technologies are the third-largest area.

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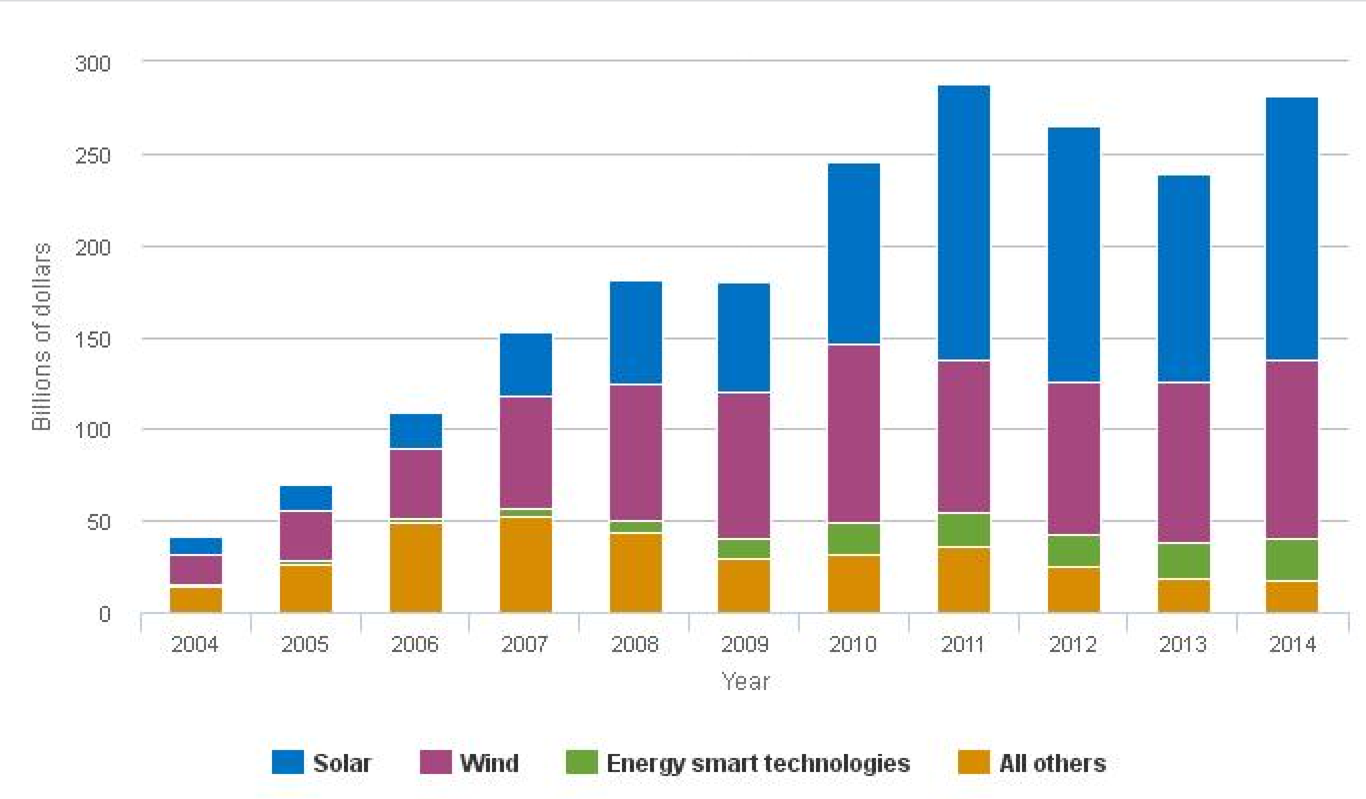
[i] Bloomberg's data include investment in renewable energy, biofuels, energy efficiency, smart grid and other energy technologies, CO_2 capture and storage, and infrastructure investments targeted purely at integrating clean energy. Investment in solar hot water, combined heat and power, renewable heat, and nuclear are excluded, as are the proceeds of mergers and acquisitions (which do not contribute to new investment).

Figure 6-44

Private investment in clean energy technologies, by selected technology: 2004–14



NOTES: Clean energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies. Private investment includes asset finance, small distributed capacity, venture capital, private equity, reinvested equity, and public markets. Mergers and acquisitions are excluded.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2014).

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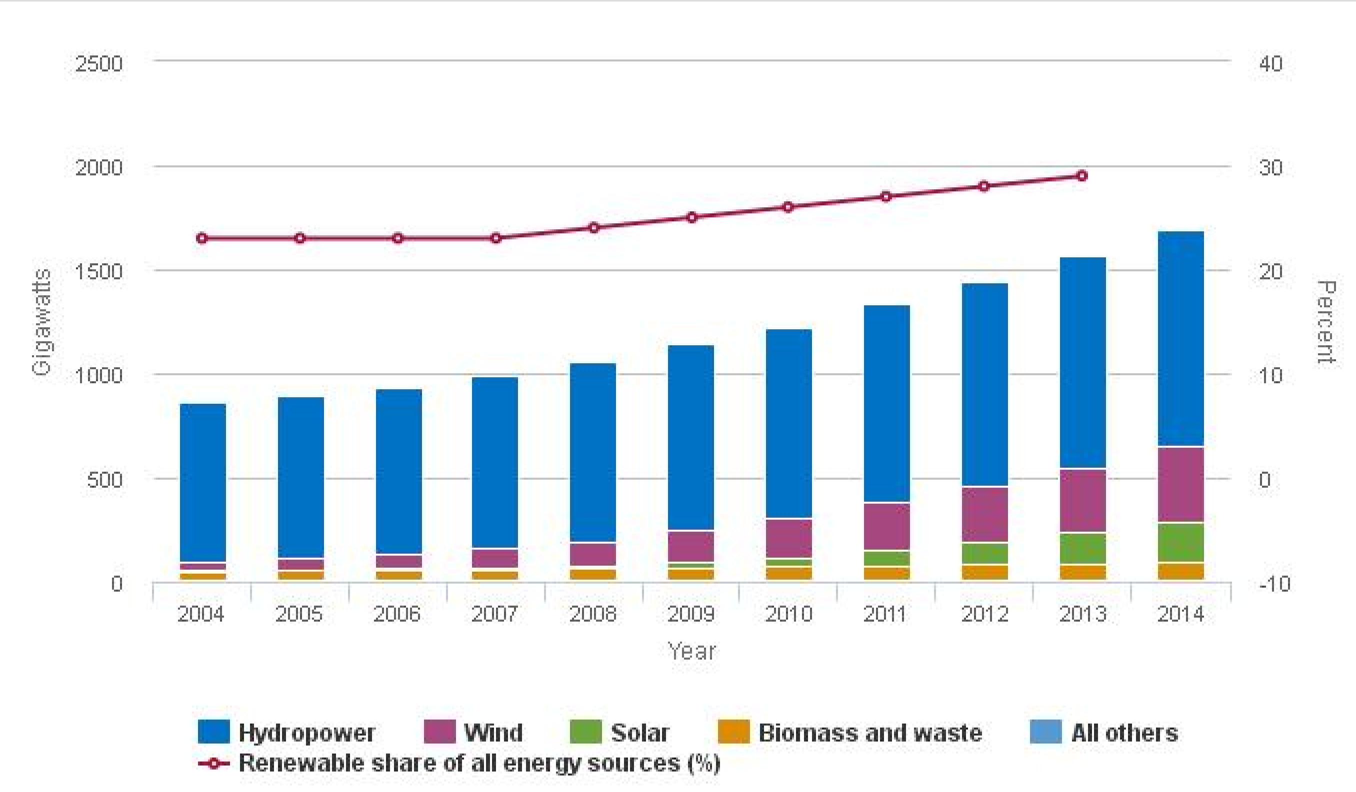
Figure 6-45

Global generation capacity of renewable energy, by source: 2004–14



NA = not available.

NOTES: Renewable energy includes biomass and waste, geothermal, hydropower, marine, solar, and wind. Renewable share of total is not available for 2014.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2014).

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Trends in global private investment. Between 2005 and 2014, global clean energy investment quadrupled from $70 billion to $281 billion (Figure 6-44; Appendix Table 6-64). After rising rapidly after the recession, investment fell from $288 billion in 2011 to $240 billion in 2013 before rebounding to $281 billion in 2014. Postrecession global investment growth has slowed because of the sluggish global economy, cutbacks by many governments on incentives to support clean energy, and declining costs of solar photovoltaics and wind technologies, which in turn have reduced the per-unit cost of investment in these technologies.

Solar led the growth of clean energy investment over the last decade, rising 10-fold from $14 billion to $144 billion. Investment in wind energy grew from $28 billion to $97 billion during this period. Investment in energy smart technologies also increased rapidly, although from a much lower level.

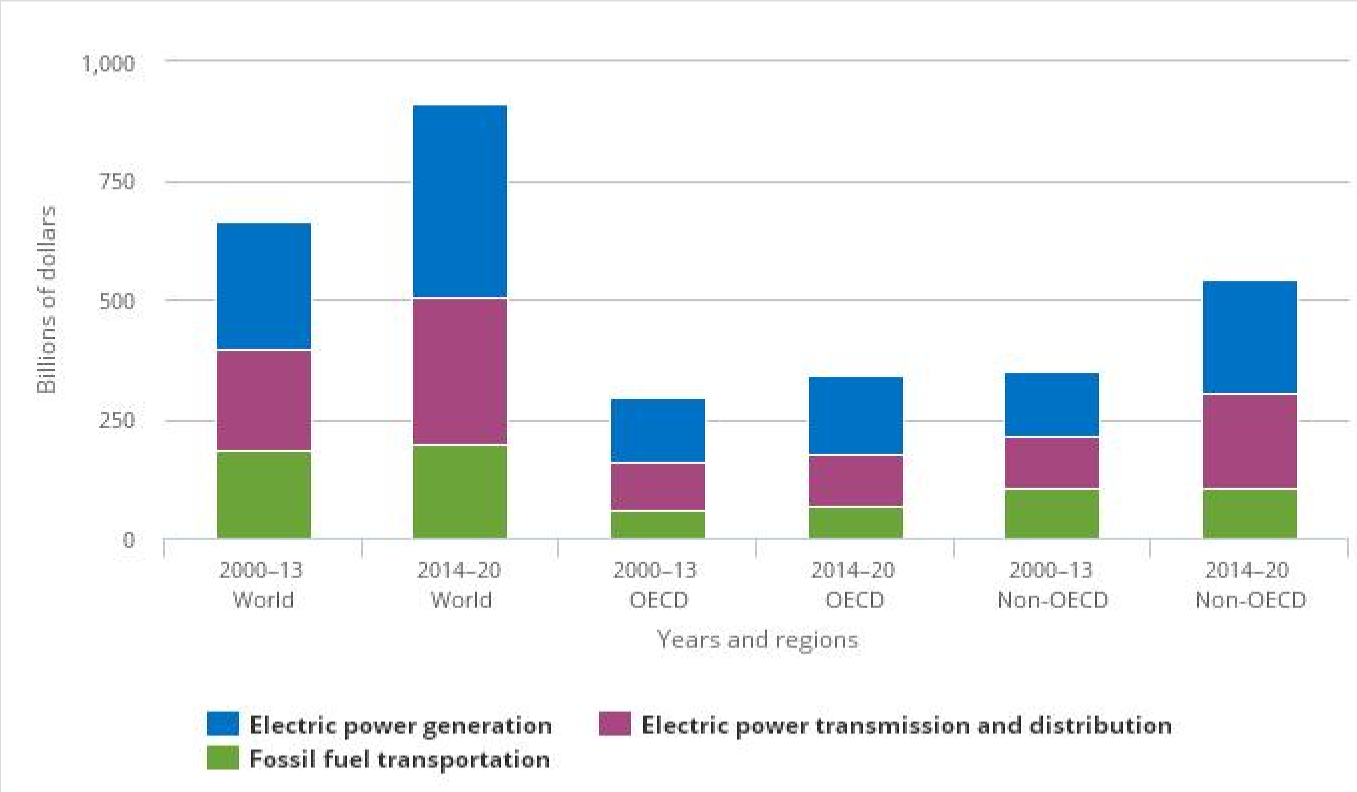
The large expansion of investment in wind and solar over the last decade has been accompanied by ever-increasing solar and wind generation capacity (Figure 6-45). Global solar and wind generation capacity jumped from 60 gigawatts in 2005 to 552 gigawatts in 2014. In 2014, the world added nearly 100 gigawatts of solar and wind generation capacity, an all-time record. The rapid expansion of solar and wind generation has driven the increase in the renewable share of all energy generation sources during this period.

The rise of clean energy investment has occurred in a broader environment of rising investment in *energy infrastructure*. Energy infrastructure consists of power plants, electricity transmission and distribution grids, and the transportation of fossil fuels. The International Energy Agency (IEA) estimates that public and private investment in energy infrastructure more than doubled from $290 billion in 2000 to $650 billion in 2012. Most of this growth occurred in financing of new power plants. The rapid rise in energy infrastructure investment has been driven by growing energy demand, particularly in developing countries. Growth in investment in renewable energy has been driven by the desire to reduce dependence on fossil fuels and reduce CO_2 emissions. In addition, clean energy has been attractive for developing countries because sourcing distributed generation from clean energy sources reduces costly investment in utility plants and distribution networks.

Investment in energy infrastructure, including the clean energy sector, is likely to continue growing. The IEA projects that global investment in energy infrastructure will average an annual $900 billion during 2014–20 compared with $660 billion in 2000–13 (Figure 6-46). Investment in renewable energy sources is projected to increase substantially in both OECD and non-OECD countries (Table 6-7 and Table 6-8).

Figure 6-46

Average annual investment in energy infrastructure for selected regions: 2000–13 and 2014–20



OECD = Organisation for Economic Co-operation and Development.

SOURCE: International Energy Agency, World Energy Investment Outlook, http://www.iea.org/publications/freepublications/publication/weo-2014-special-report---investment.html, accessed 15 March 2015.

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Table 6-7 Average annual investment in the power sector of the OECD, United States, and the EU, by energy source: 2000–13 and 2014–20

(Billions of dollars)

	OECD		United States		EU	
Energy source	2000–13	2014–20	2000–13	2014–20	2000–13	2014–20
All energy sources	135	166	35	52	66	61
Renewables	87	110	16	31	53	47
Wind	29	49	9	8	17	24
Solar	33	25	4	9	23	14
Bioenergy	11	13	2	8	8	3
Hydro	11	14	1	2	3	4
All others	3	9	0	4	2	2

	OECD		United States		EU	
Energy source	2000–13	2014–20	2000–13	2014–20	2000–13	2014–20
Nuclear	4	17	0	5	1	6
Fossil fuels	44	39	19	16	12	8

EU = European Union; OECD = Organisation for Economic Co-operation and Development.

SOURCE: International Energy Agency, World Energy Investment Outlook, http://www.iea.org/publications/freepublications/publication/WEIO2014.pdf, accessed 15 March 2015.

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Table 6-8 **Average annual investment in the power sector of non-OECD countries, China, and India, by energy source: 2000–13 and 2014–20**

(Billions of dollars)

	Non-OECD		China		India	
Energy source	2000–13	2014–20	2000–13	2014–20	2000–13	2014–20
All energy sources	134	241	71	110	46	32
Renewables	67	131	36	72	7	15
Wind	14	35	9	25	3	6
Solar	5	23	3	13	0	3
Bioenergy	6	9	2	3	1	1
Hydro	41	59	22	28	3	4
All others	1	5	0	3	0	1
Nuclear	5	29	2	15	7	3
Fossil fuels	62	81	33	23	32	14

OECD = Organisation for Economic Co-operation and Development.

SOURCE: International Energy Agency, World Energy Investment Outlook, http://www.iea.org/publications/freepublications/publication/WEIO2014.pdf, accessed 15 March 2015.

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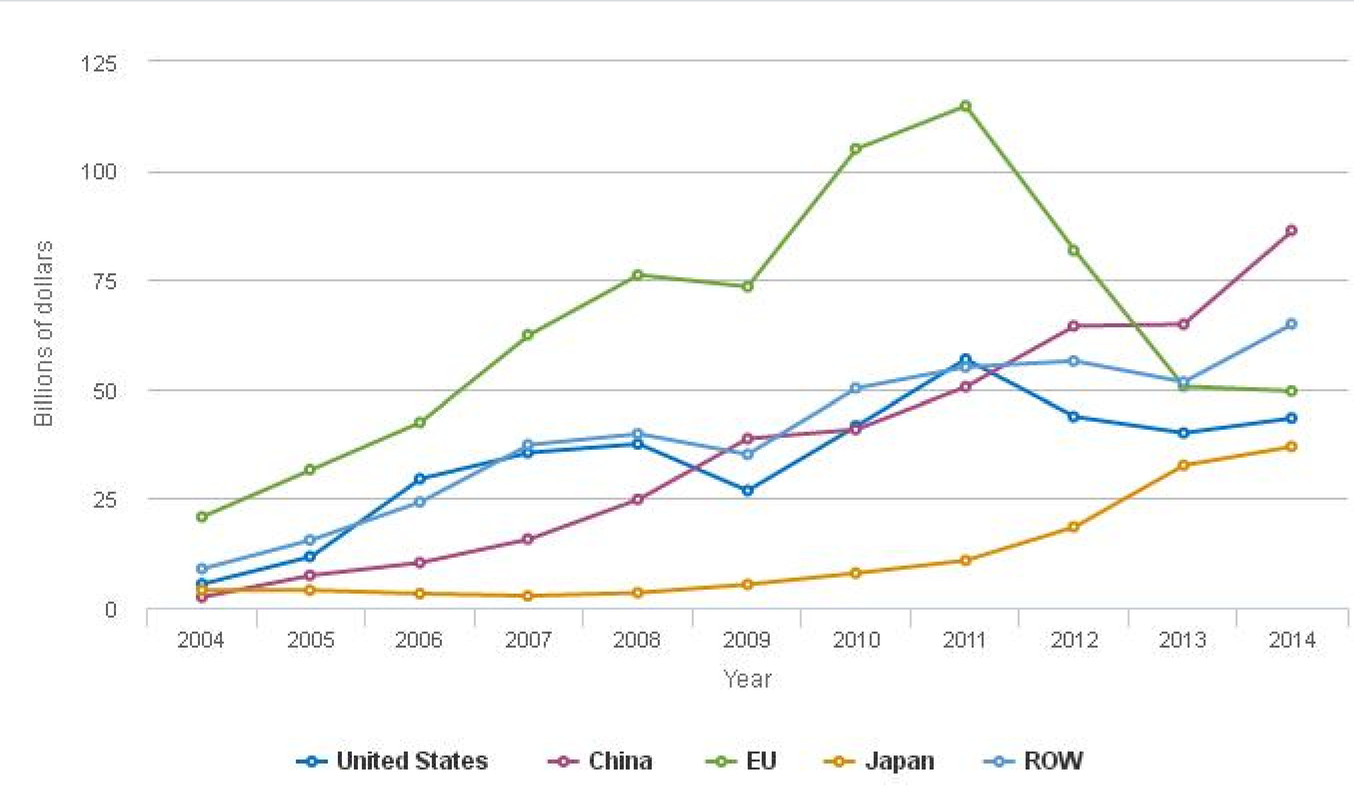
Patterns and trends in commercial investment of major economies. China leads the world in attracting clean energy investment (31% global share) (Appendix Table 6-64). The EU is second (18%), closely followed by the United States (15%). Japan is the fourth largest (13%).

China's private investment rose exponentially from $10 billion in 2006 to $86 billion in 2014 (Figure 6-47; Appendix Table 6-64). The uninterrupted growth of clean energy investments in China reflects the government's policies targeted at wind and solar energy to make China a major world producer in these technologies, reduce China's reliance on fossil fuels, and cut its CO_2 emissions. Investment in solar has driven China's growth over the last 5 years, climbing from $6 billion to $39 billion, making China the leading country in solar investment. China's rapid rise reflects its emergence as a major manufacturer of low-cost photovoltaic modules, as well as growing installation of utility scale and residential solar installations in China. China has also had impressive growth in investment in wind energy (from $27 billion in 2010 to $38 billion in 2014), making China the leading country in investment in wind.

Figure 6-47

Private investment in clean energy technologies, by selected region/country/economy: 2004–14



EU = European Union; ROW = rest of world.

NOTES: Clean energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies. Private investment includes asset finance, small distributed capacity, venture capital, private equity, reinvested equity, and public markets. Mergers and acquisitions are excluded.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2014).

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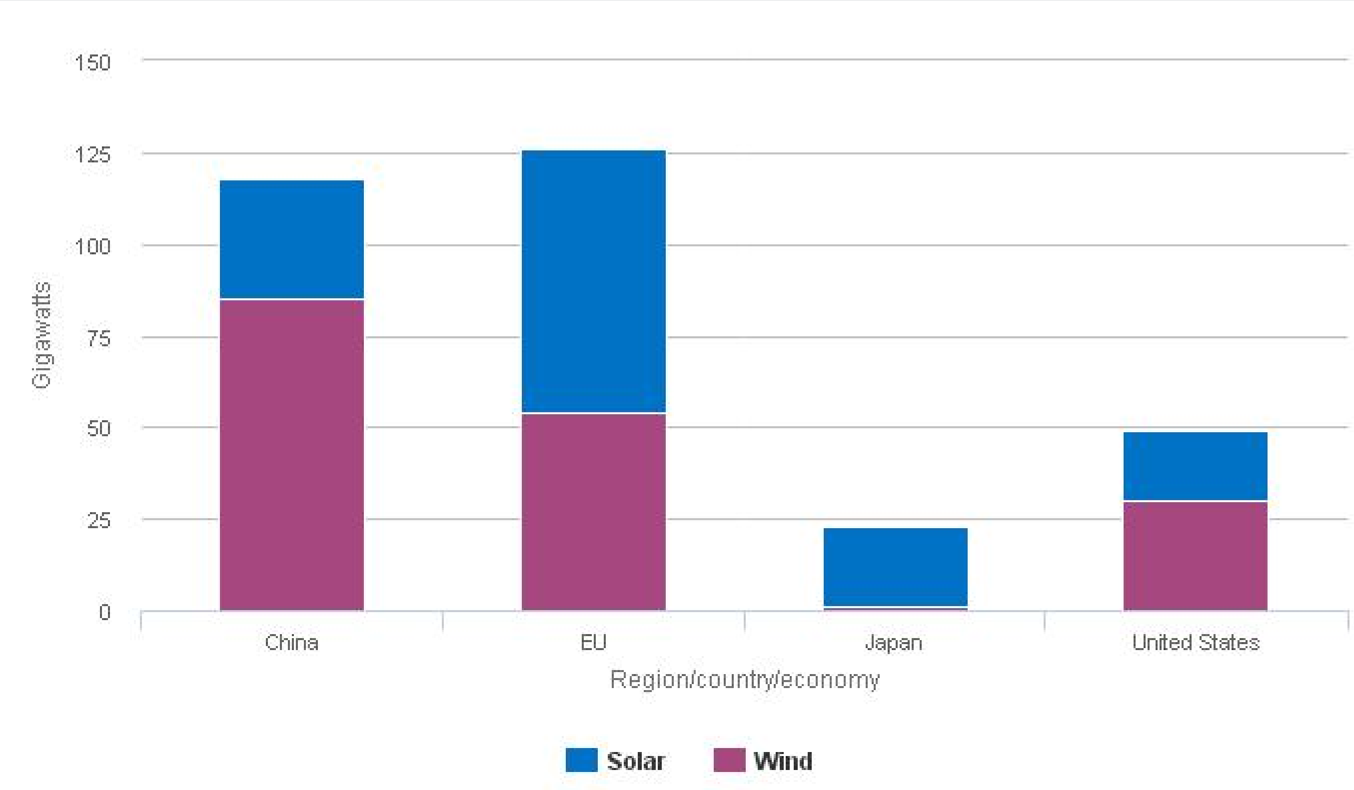
China's solar and wind generation capacity has grown rapidly, showing that its clean energy sector is shifting from a primary focus on exports to domestic consumption. Between 2010 and 2014, China's wind and solar generation capacity increased by nearly 120 gigawatts, the largest increase of any single country (Figure 6-48).

Figure 6-48

Cumulative installation of generation capacity of solar and wind, by energy source and selected region/country/economy: 2010–14



EU = European Union.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2014).

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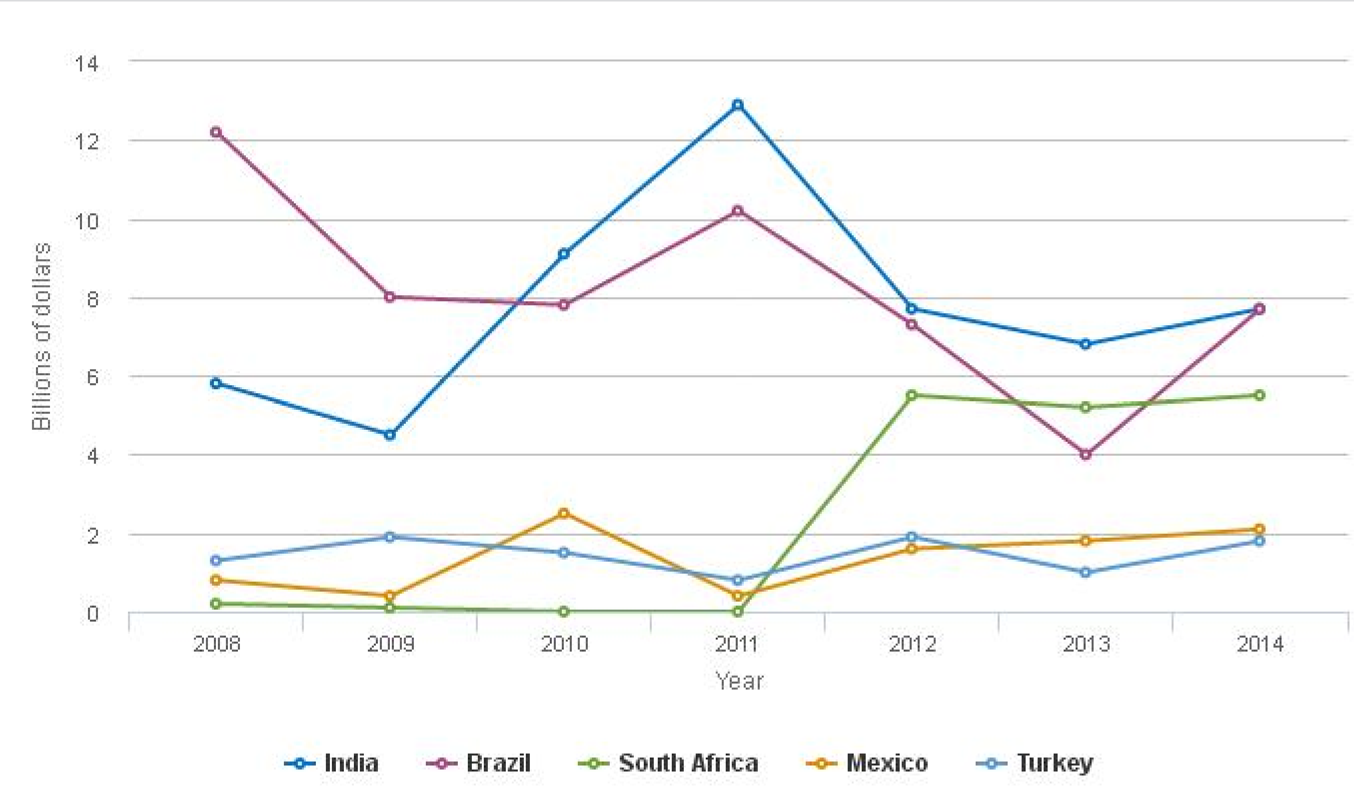
In other developing countries, Brazil and India each attracted $8 billion with the bulk of funds supporting wind power in Brazil and wind and solar in India (Figure 6-49; Appendix Table 6-64). In both, investment scaled back substantially, reflecting economic, regulatory, and political factors. South Africa has had one of the fastest growth rates in commercial investment among developing countries over the last several years.

Figure 6-49

Private investment in clean energy technologies, by selected country: 2008–14



NOTES: Clean energy technologies include biomass, geothermal, wind, solar, biofuels, and energy smart and efficiency technologies. Private investment includes asset finance, small distributed capacity, venture capital, private equity, reinvested equity, and public markets. Mergers and acquisitions are excluded.

SOURCE: Bloomberg New Energy Finance, http://bnef.com/, special tabulations (2014).

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Investment in the EU has fallen sharply because of cutbacks in clean energy incentives in response to fiscal austerity measures and the declining per-unit cost of investment in solar and wind technologies (Figure 6-47; Appendix Table 6-64). EU member countries with major declines in investment have included Germany, Spain, and Italy. Despite the recent curtailment of clean energy investment, the EU added a combined 125 gigawatts in solar and wind generation capacity between 2010 and 2014 (Figure 6-48).

Investment in the United States has been uneven. After the expiration of temporary financing provisions and subsidies led to a postrecession spike of $57 billion in 2011, investment fell to about $40 billion in 2012–14 (Figure 6-47; Appendix Table 6-64). The U.S. global share slipped from 20% to 15% during this period. The holding pattern of U.S. clean energy investment has been attributed to investor uncertainty over the future of the production tax credit and other clean energy incentives, as well as lack of clarity over U.S. energy policy. Investment in wind energy declined from $14 billion to $7 billion between 2012 and 2014 because of uncertainty over the timing and provisions of the production tax credit, which was extended by Congress in late 2013. Solar investment grew strongly, driven by utility-scale installations and soaring growth in residential installations because of the plunge in cost of photovoltaics and the adoption of leasing and other innovative financing methods.

Between 2010 and 2014, the United States added a combined 49 gigawatts in solar and wind generation capacity, less than half the amount of capacity added in China or the EU (Figure 6-48).

Clean energy investment in Japan has soared largely because of generous government incentives for solar investment enacted several years ago in response to the government's push to diversify energy sources in the wake of the Fukushima nuclear reactor accident (Figure 6-47; Appendix Table 6-64). Investment in solar climbed from $7 billion to $34 billion between 2010 and 2014, propelling total investment to $37 billion in 2014. Between 2010 and 2014, Japan added 22 gigawatts in solar energy capacity (Figure 6-48).

In other developed economies, Canada's investment has grown rapidly, climbing from $1 billion to $8 billion over the last decade, led by wind and solar (Appendix Table 6-64).

Patenting of Clean Energy and Pollution Control Technologies

Clean energy and pollution control technology patents comprise four broad areas: alternative energy, with 5,300 patents granted; energy storage, with 1,700 patents; smart grid, with 1,300 patents; and pollution mitigation, with 2,400 patents (Appendix Table 6-65, Appendix Table 6-66, Appendix Table 6-67, Appendix Table 6-68, and Appendix Table 6-69). These broad categories are further divided into 28 finer technology areas. (For more information on this classification of clean energy patent technologies, which was developed by NSF, please see the NCSES working paper, *Identifying Clean Energy Supply and Pollution Control Patents*.[i])

The number of patents in these technologies has soared since 2009, in line with the rapid growth of all USPTO patents (Figure 6-50; Appendix Table 6-65).[ii] Five technologies—solar, hybrid and electric vehicles, smart grid, fuel cell, and battery—led the growth of clean energy patents between 2003 and 2014 (Appendix Table 6-68, Appendix Table 6-70, Appendix Table 6-71, Appendix Table 6-72, and Appendix Table 6-73):

- Solar energy increased by more than fivefold to reach 1,600 patents.
- Hybrid and electric vehicles tripled to reach 1,300 patents.
- Smart grid more than doubled to reach 1,300 patents.
- Battery more than doubled to reach 800 patents.
- Fuel cell almost doubled to reach 800 patents.

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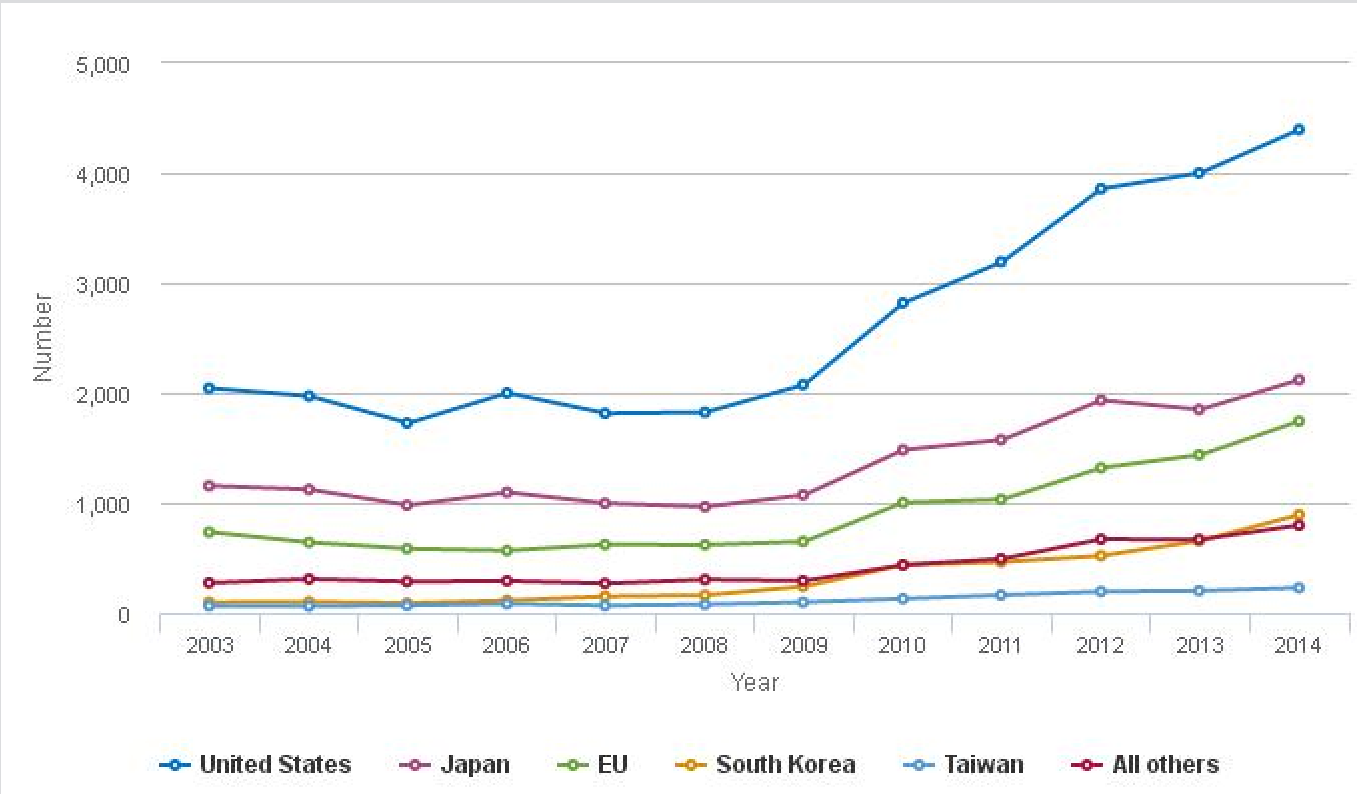
[i] See D'Amato (2015) for more information on NSF's classification of clean energy patents.

[ii] The USPTO initiated a green technology pilot program on 7 December 2009 that expedites processing of some applications related to green technologies. For more information, see http://www.uspto.gov/patents/init_events/green_tech.jsp.

Figure 6-50

USPTO patents in alternative energy and pollution control technologies, by selected region/country/economy of inventor: 2003–14



EU = European Union; USPTO = U.S. Patent and Trademark Office.

NOTES: Clean energy and pollution control technologies include alternative energy, energy storage, smart grid, and pollution mitigation. Alternative energy includes solar, wind, nuclear, hydropower, wave/tidal/ocean, geothermal, and electric/hybrid. Energy storage includes batteries, compressed air, flywheels, superconductivity, magnet energy systems, ultracapacitors, hydrogen production and storage, and thermal energy. Pollution mitigation includes recycling; control of air, water, and solid waste pollution; environmental remediation; cleaner coal; and capture and storage of carbon and other greenhouse gases. Technologies are classified by The Patent Board™. Patent grants are fractionally allocated among regions/countries on the basis of the proportion of the residences of all named inventors.

SOURCE: The Patent Board™, Proprietary Patent database, special tabulations (2014). See appendix table 6-65.

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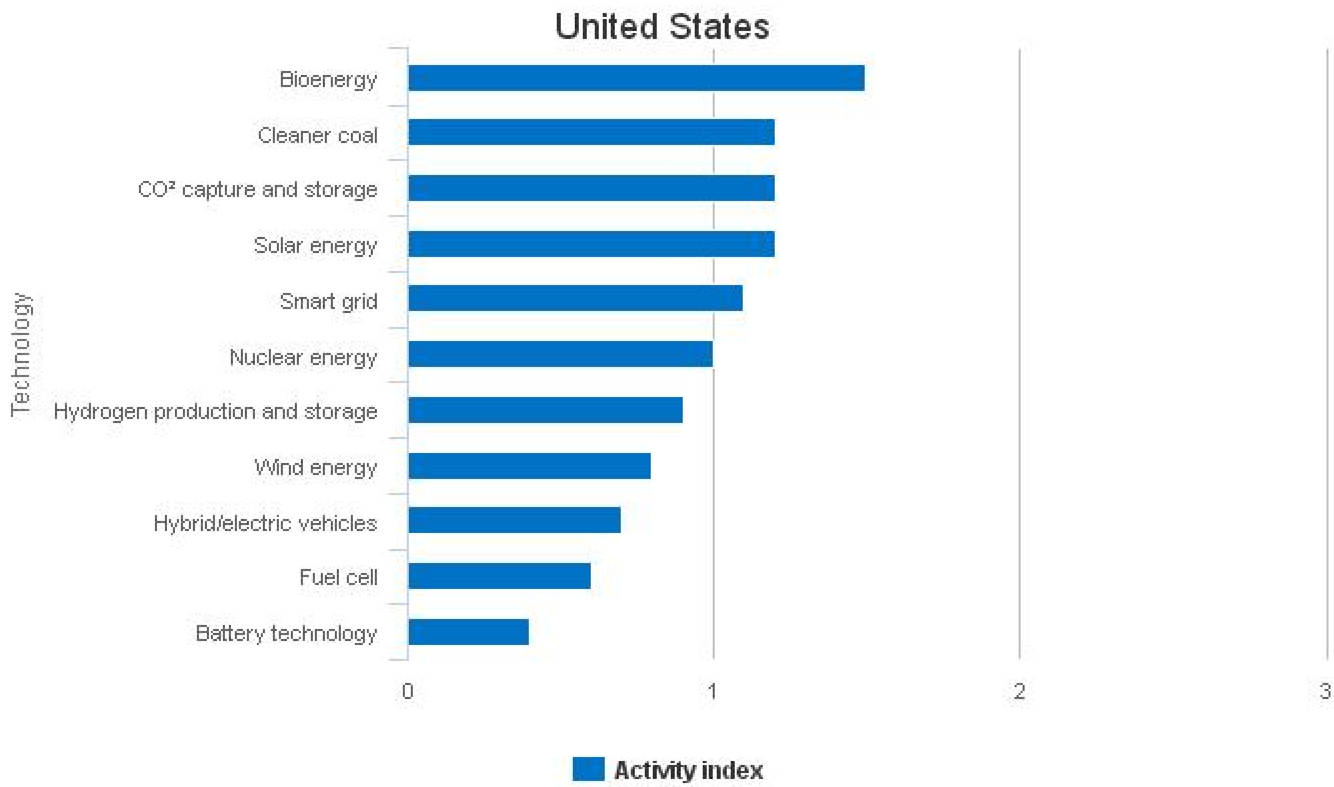
U.S. resident inventors were granted 43% of all clean energy and pollution control patents in 2014. The next three largest recipient countries are Japan (21%), the EU (17%), and South Korea (9%) (Figure 6-50). Between 2003 and 2014, Japan's share fell from 26% to 21%. South Korea's share rose from 2% to 9% because of strong growth in electric and hybrid vehicles, fuel cell, and battery technology (Appendix Table 6-71, Appendix Table 6-72, and Appendix Table 6-73). Patents granted to China and Taiwan have been increasing rapidly, though from a very low base (Appendix Table 6-65). In 2014, China and Taiwan's shares of total patents were 2% each, up from 1% or less in 2003.

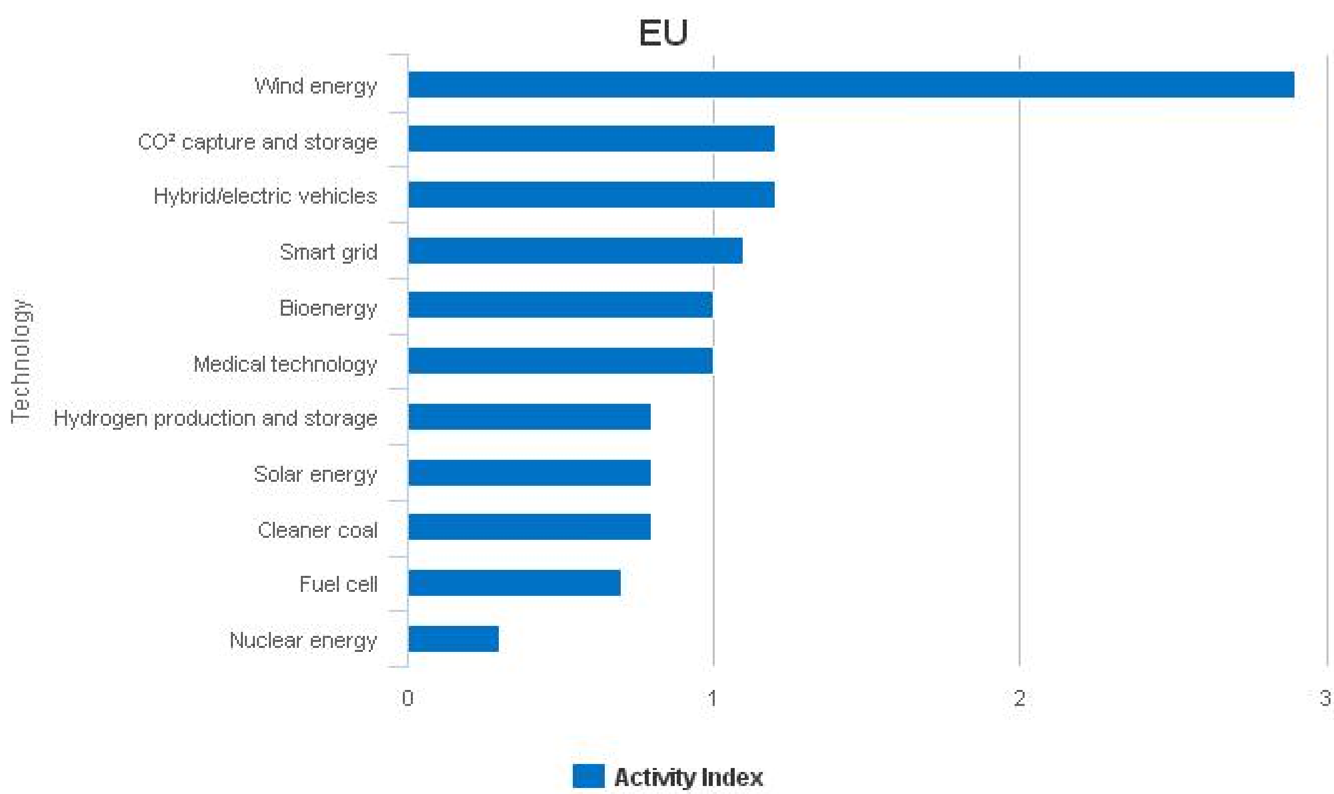
Patent technology activity indexes measure the world share of a region, country, or economy in clean energy and clean technologies relative to its world share in patents in all technologies. A ratio greater than 1 signifies that patents by a region/country/economy are concentrated in a particular technology.

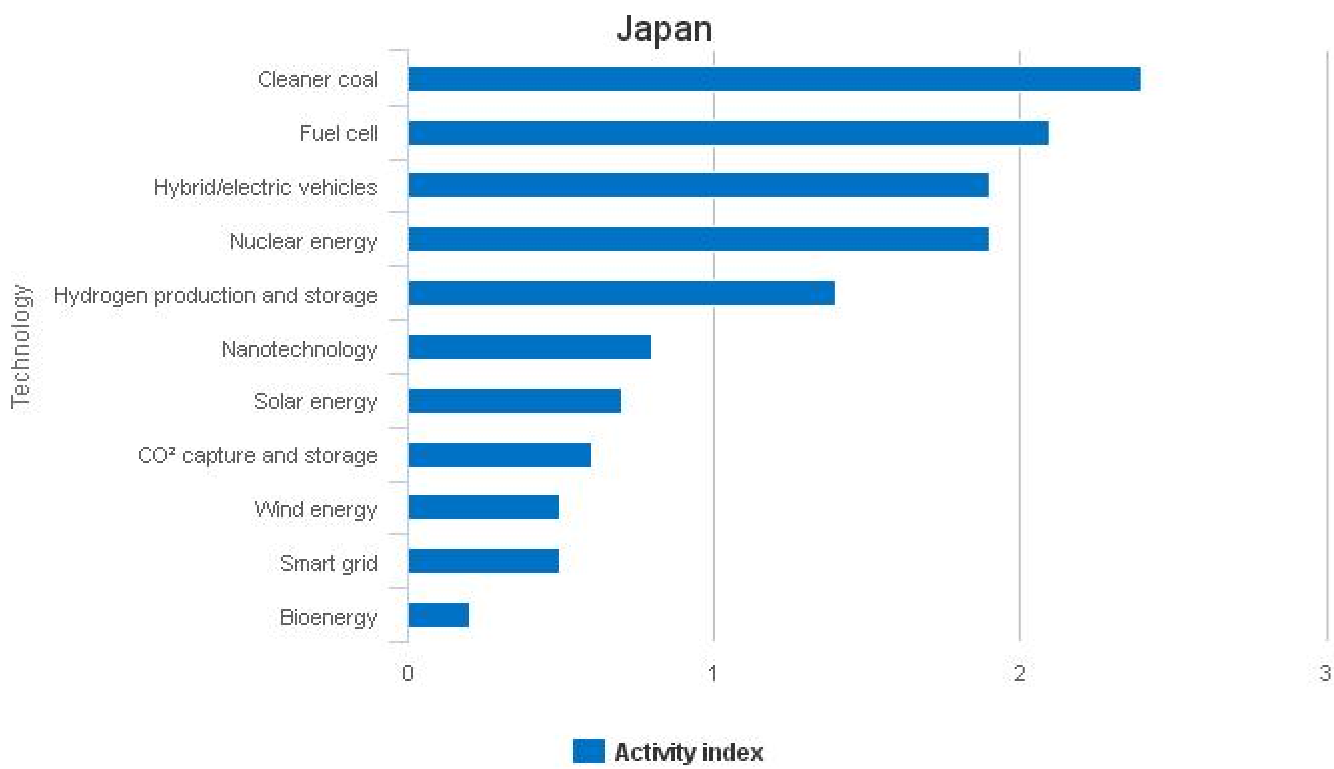
The U.S. has a high concentration in bioenergy, cleaner coal, CO_2 capture and storage, solar, and smart grid technologies, and relatively low patent activity in wind, electric and hybrid vehicles, fuel cells, and batteries (Figure 6-51; Appendix Table 6-68 and Appendix Table 6-70, Appendix Table 6-71, Appendix Table 6-72, Appendix Table 6-73, Appendix Table 6-74, Appendix Table 6-75, Appendix Table 6-76, and Appendix Table 6-77). The higher-than-average patenting activity in solar may reflect the substantial level of venture capital investment to commercialize advanced and leading-edge solar technologies. Similarly, U.S. patenting activity in CO_2 capture and storage may reflect substantial U.S. public investment in RD&D in this technology area, which requires multimillion dollar investment to build demonstration coal generation plants to test and develop this technology.

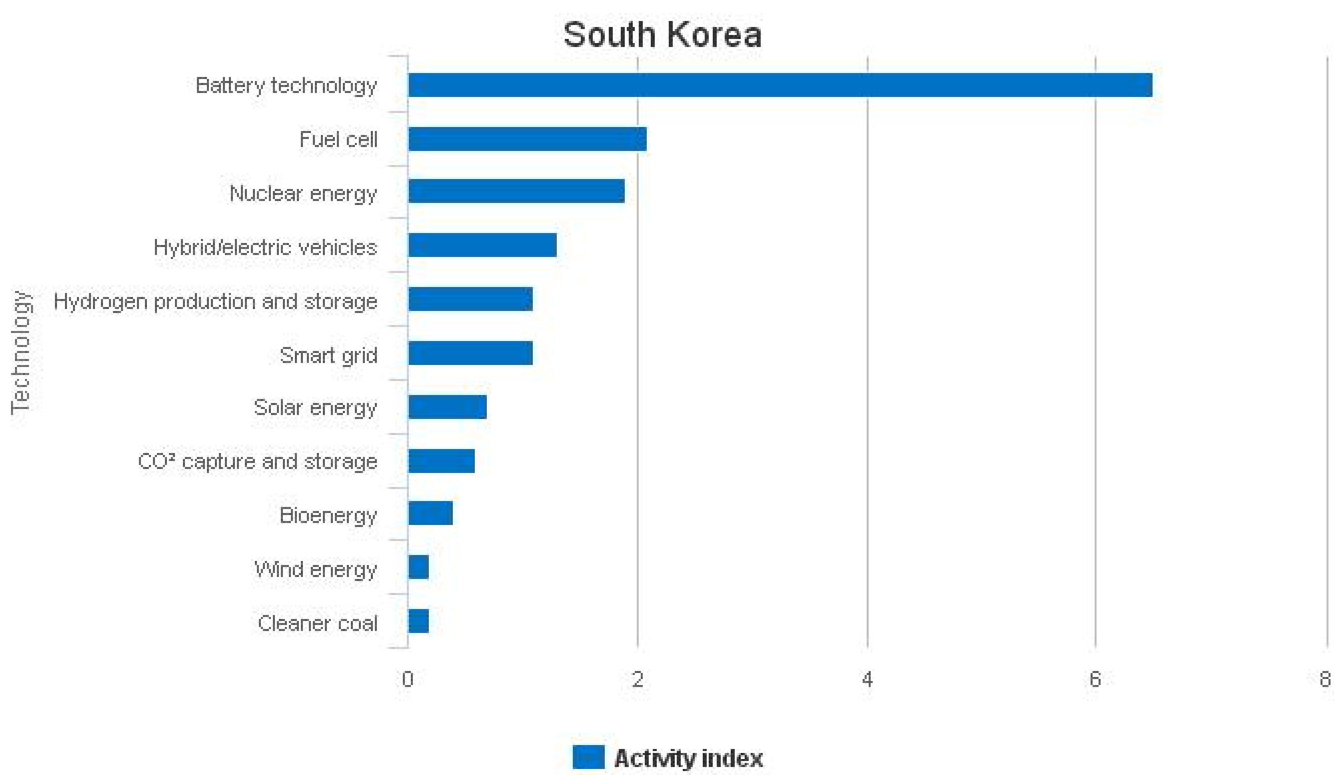
Figure 6-51

Patent activity index of selected clean energy technologies for the United States, the EU, Japan, and South Korea: 2012–14









EU = European Union.

NOTES: A patent activity index is the ratio of a country’s share of a technology area to its share of all patents. A patent activity index greater (less) than 1.0 indicates that the country is relatively more (less) active in the technology area. Patents are classified by the World Intellectual Property Organization's (WIPO's) classification of patents, which classifies International Patent Classification (IPC) codes under 35 technical fields. IPC reformed codes, which take into account changes that were made to the WIPO classification in 2006 under the eighth version of the classification, were used to prepare these data. Fractional counts of patents were assigned to each IPC code on patents to assign the proper weight of a patent to the corresponding IPC codes and their associated technical fields under the classification. Patents are fractionally allocated among regions/countries/economies based on the proportion of residences of all named inventors.

SOURCES: Science-Metrix, LexisNexis, and SRI International.

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The EU has a very high concentration in wind; relatively high concentrations in CO_2 capture and storage, electric and hybrid vehicles, and smart grid; and relatively low concentrations in hydrogen production and storage, solar, cleaner coal, and nuclear energy (Figure 6-51; Appendix Table 6-68, Appendix Table 6-70, Appendix Table 6-71, Appendix Table 6-73, Appendix Table 6-75, Appendix Table 6-76, Appendix Table 6-77, Appendix Table 6-78, and Appendix Table 6-79). The EU's higher-than-average activity in CO_2 capture and storage may reflect the EU's substantial public investment in RD&D in this technology area.

Japan has a high concentration of patents in fuel cells, cleaner coal, nuclear energy, electric and hybrid technologies, and hydrogen production and storage but relatively low activity in solar, CO_2 capture and storage, wind, smart grid, and bioenergy (Figure 6-51; Appendix Table 6-68, Appendix Table 6-70, Appendix Table 6-71, Appendix Table 6-72, Appendix Table 6-73, and Appendix Table 6-74, Appendix Table 6-76 – Appendix Table 6-77, and Appendix Table 6-79).

South Korea has a very high concentration in batteries and a high concentration in fuel cells, nuclear energy, hybrid and electric vehicles, hydrogen production and storage, and smart grid (Figure 6-51; Appendix Table 6-68, Appendix Table 6-71, Appendix Table 6-72, Appendix Table 6-73, Appendix Table 6-78, and Appendix Table 6-79). It has lower-than-average activity in all other technologies.

Conclusion

The United States continues to be the leading global economy in technology-based industries, as measured by its overall performance, market position in these industries, and position in patenting and other measures of innovation-related activities. The strong competitive position of the U.S. economy overall is tied to continued U.S. global leadership in many KTI industries. The United States continues to hold the dominant market position in commercial KI services, which account for nearly one-fifth of global economic activity, and in HT manufacturing industries. The U.S. trading position in commercial KI services and licensing of patents and trade secrets remains strong, as evidenced by the continued U.S. surpluses in these areas. The United States is the second-largest source of public RD&D in clean energy and related technologies and attracts the most venture capital financing of any country in these technologies. Output of U.S. KTI industries has recovered from the global recession in line with the strengthening economy.

The overall U.S. ranking notwithstanding, its market position in almost all of the KTI industries has been static or has slipped. U.S. production and employment have fallen sharply in the HT manufacturing industries of communications and computers, coinciding with U.S. companies moving assembly and other activities to China and other countries. The U.S. trade position in these products has shifted to deficit because exports have declined and imports have increased. Although output of U.S. KTI industries has had a strong recovery from the global recession, gains in employment have been limited and confined to commercial KI services.

For much of the 2000s, the EU's position was similar to that of the United States—relatively strong overall economic performance and flat or slight declines in its market position in KTI industries. But the EU's KTI industries have not recovered from the global recession because of the EU's weak economy, resulting in an erosion of the market position of its KTI industries.

Over the last decade, Japan's economy showed less dynamism compared with the economies of the United States and the EU, and its market position declined steeply in many KTI industries. Japan's loss of market position in HT manufacturing industries was due, in part, to Japanese companies shifting production to China and other Asian economies. Japan's KTI industries have not recovered from the global recession, coinciding with the uncertain and halting progress of the economy.

China has become a leading provider of commercial KI services and the second-largest global producer in HT manufacturing industries and has narrowed its gap with the United States. China has become the largest global exporter in HT manufactured products and has developed surpluses in trade of HT manufacturing products and commercial KI services. It has become the world's largest recipient of commercial financing for clean energy and a leading producer in the solar industry. However, China's indicators of indigenous capability in KTI industries and other areas are uneven. Much of China's HT manufacturing output is controlled by MNCs that import higher-value components from other countries for final assembly in, and export from, China. Chinese companies have made limited progress in more technologically advanced and higher-end manufacturing activities. In an indicator of innovative capacity, China's share of USPTO and economically valuable patents has grown but remains low.

Other developing economies—including Brazil and India—showed progress in their overall economic growth and technological capabilities and improved their market positions in many KTI industries. In recent years, their previously strong KTI growth rates have moderated but remain ahead of those of many developed countries.

Glossary

Affiliate: A company or business enterprise located in one country but owned or controlled (10% or more of voting securities or equivalent) by a parent company in another country; may be either incorporated or unincorporated.

Commercial knowledge-intensive (KI) services: KI services that are generally privately owned and compete in the marketplace without public support. These services are business, information, and financial services.

Company or firm: A business entity that is either in a single location with no subsidiaries or branches or the topmost parent of a group of subsidiaries or branches.

European Union (EU): As of September 2015, the EU comprised 28 member nations: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. Unless otherwise noted, data on the EU include all 28 member countries.

Foreign direct investment: Financial investment by which a person or an entity acquires a lasting interest in and a degree of influence over the management of a business enterprise in a foreign country.

Gross domestic product (GDP): The market value of all final goods and services produced within a country within a given period of time.

High-technology (HT) manufacturing industries: Those that spend a relatively high proportion of their revenue on R&D, consisting of aerospace, pharmaceuticals, computers and office machinery, semiconductors and communications equipment, and scientific (medical, precision, and optical) instruments.

Information and communications technologies (ICT) industries: A subset of knowledge- and technology-intensive industries, consisting of two high-technology manufacturing industries, computers and office machinery and communications equipment and semiconductors, and two knowledge-intensive services industries, information and computer services, which is a subset of business services.

Intellectual property: Intangible property resulting from creativity that is protected in the form of patents, copyrights, trademarks, and trade secrets.

Intra-EU exports: Exports from European Union (EU) countries to other EU countries.

Knowledge- and technology-intensive (KTI) industries: Those that have a particularly strong link to science and technology. These industries are five service industries, financial, business, communications, education, and health, and five manufacturing industries, aerospace, pharmaceuticals, computers and office machinery, semiconductors and communications equipment, and scientific (medical, precision, and optical) instruments.

Knowledge-intensive (KI) industries: Those that incorporate science, engineering, and technology into their services or the delivery of their services, consisting of business, information, education, financial, and health services.

Normalizing: To adjust to a norm or standard.

Productivity: The efficiency with which resources are employed within an economy or industry, measured as labor or multifactor productivity. Labor productivity is measured by gross domestic product (GDP) or output per unit of labor. Multifactor productivity is measured by GDP or output per combined unit of labor and capital.

Triadic patent: A patent for which patent protection has been applied within the three major world markets: the United States, Europe, and Japan.

Value added: A measure of industry production that is the amount contributed by a country, firm, or other entity to the value of the good or service. It excludes the country, industry, firm, or other entity's purchases of domestic and imported supplies and inputs from other countries, industries, firms, and other entities.

Value chain: A chain of activities to produce goods and services that may extend across firms or countries. These activities include design, production, marketing and sales, logistics, and maintenance.

Venture capitalist: Venture capitalists manage the pooled investments of others (typically wealthy investors, investment banks, and other financial institutions) in a professionally managed fund. In return, venture capitalists receive ownership equity and almost always participate in managerial decisions.

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